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(54) Recombinant immunoglobulin preparations, methods for their preparation, DNA sequences, expression vectors and recombinant host cells therefor.

(57) Recombinant DNA techniques are used to produce both immunoglobulins which are analogous to those normally found in vertebrate systems and to take advantage of these gene modification techniques to construct chimeric or other modified forms.

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5 RECOMBINANT IMMUNOGLOBULIN PREPARATIONS, METHODS
 FOR THEIR PREPARATION, DNA SEQUENCES, EXPRESSION
 VECTORS AND RECOMBINANT HOST CELLS THEREFOR

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Background of the Invention

 This invention relates to the field of immunoglobulin production
15 and to modification of naturally occurring immunoglobulin amino acid
 sequences. Specifically, the invention relates to using recombinant
 techniques to produce both immunoglobulins which are analogous to
 those normally found in vertebrate systems and to take advantage of
 these gene modification techniques to construct chimeric or other
20 modified forms.

 A. Immunoglobulins and Antibodies

 Antibodies are specific immunoglobulin polypeptides produced by
 the vertebrate immune system in response to challenge by foreign
25 proteins, glycoproteins, cells, or other antigenic foreign
 substances. The sequence of events which permits the organism to
 overcome invasion by foreign cells or to rid the system of foreign
 substances is at least partially understood. An important part of
 this process is the manufacture of antibodies which bind
30 specifically to a particular foreign substance. The binding
 specificity of such polypeptides to a particular antigen is highly
 refined, and the multitude of specificities capable of being
 generated by the individual vertebrate is remarkable in its
 complexity and variability. Thousands of antigens are capable of

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eliciting responses, each almost exclusively directed to the particular antigen which elicited it.

Immunoglobulins include both antibodies, as above described, and analogous protein substances which lack antigen specificity. The latter are produced at low levels by the lymph system and in increased levels by myelomas.

A.1 Source and Utility

Two major sources of vertebrate antibodies are presently utilized--generation in situ by the mammalian B lymphocytes and in cell culture by B-cell hybrids. Antibodies are made in situ as a result of the differentiation of immature B lymphocytes into plasma cells, which occurs in response to stimulation by specific antigens. In the undifferentiated B cell, the portions of DNA coding for the various regions on the immunoglobulin chains are separated in the genomic DNA. The sequences are reassembled sequentially prior to transcription. A review of this process has been given by Gough, Trends in Biochem Sci, 6: 203 (1981). The resulting rearranged genome is capable of expression in the mature B lymphocyte to produce the desired antibody. Even when only a single antigen is introduced into the sphere of the immune system for a particular mammal, however, a uniform population of antibodies does not result. The in situ immune response to any particular antigen is defined by the mosaic of responses to the various determinants which are present on the antigen. Each subset of homologous antibody is contributed by a single population of B cells--hence in situ generation of antibodies is "polyclonal".

This limited but inherent heterogeneity has been overcome in numerous particular cases by use of hybridoma technology to create "monoclonal" antibodies (Kohler, et al., Eur. J. Immunol., 6: 511 (1976)). In this process, splenocytes or lymphocytes from a mammal which has been injected with antigen are fused with a tumor cell

line, thus producing hybrid cells or "hybridomas" which are both immortal and capable of producing the genetically coded antibody of the B cell. The hybrids thus formed are segregated into single genetic strains by selection, dilution, and regrowth, and each strain thus represents a single genetic line. They therefore produce immunoreactive antibodies against a desired antigen which are assured to be homogenous, and which antibodies, referencing their pure genetic parentage, are called "monoclonal". Hybridoma technology has to this time been focused largely on the fusion of murine lines, but human-human hybridomas (Olsson, L. et al., Proc. Natl. Acad. Sci. (USA), 77: 5429 (1980)); human-murine hybridomas (Schlom, J., et al. (ibid) 77: 6841 (1980)) and several other xenogenic hybrid combinations have been prepared as well. Alternatively, primary, antibody producing, B cells have been immortalized in vitro by transformation with viral DNA.

Polyclonal, or, much more preferably, monoclonal, antibodies have a variety of useful properties similar to those of the present invention. For example, they can be used as specific immunoprecipitating reagents to detect the presence of the antigen which elicited the initial processing of the B cell genome by coupling this antigen-antibody reaction with suitable detection techniques such as labeling with radioisotopes or with enzymes capable of assay (RIA, EMIT, and ELISA). Antibodies are thus the foundation of immuno diagnostic tests for many antigenic substances. In another important use, antibodies can be directly injected into subjects suffering from an attack by a substance or organism containing the antigen in question to combat this attack. This process is currently in its experimental stages, but its potential is clearly seen. Third, whole body diagnosis and treatment is made possible because injected antibodies are directed to specific target disease tissues, and thus can be used either to determine the presence of the disease by carrying with them a

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suitable label, or to attack the diseased tissue by carrying a suitable drug.

Monoclonal antibodies produced by hybridomas, while

5 theoretically effective as suggested above and clearly preferable to polyclonal antibodies because of their specificity, suffer from certain disadvantages. First, they tend to be contaminated with other proteins and cellular materials of hybridoma, (and, therefore, mammalian) origin. These cells contain additional materials,

10 notably nucleic acid fragments, but protein fragments as well, which are capable of enhancing, causing, or mediating carcinogenic responses. Second, hybridoma lines producing monoclonal antibodies tend to be unstable and may alter the structure of antibody produced or stop producing antibody altogether (Kohler, G., et al., Proc.

15 Natl. Acad. Sci (USA) 77: 2197 (1980); Morrison, S.L., J. Immunol. 123: 793 (1979)). The cell line genome appears to alter itself in response to stimuli whose nature is not currently known, and this alteration may result in production of incorrect sequences. Third, both hybridoma and B cells inevitably produce certain antibodies in

20 glycosylated form (Melchers, F., Biochemistry, 10: 653 (1971)) which, under some circumstances, may be undesirable. Fourth, production of both monoclonal and polyclonal antibodies is relatively expensive. Fifth, and perhaps most important, production by current techniques (either by hybridoma or by B cell response)

25 does not permit manipulation of the genome so as to produce antibodies with more effective design components than those normally elicited in response to antigens from the mature B cell in situ. The antibodies of the present invention do not suffer from the foregoing drawbacks, and, furthermore, offer the opportunity to

30 provide molecules of superior design.

Even those immunoglobulins which lack the specificity of antibodies are useful, although over a smaller spectrum of potential uses than the antibodies themselves. In presently understood

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applications, such immunoglobulins are helpful in protein replacement therapy for globulin related anemia. In this context, an inability to bind to antigen is in fact helpful, as the therapeutic value of these proteins would be impaired by such functionality. At present, such non-specific antibodies are derivable in quantity only from myeloma cell cultures suitably induced. The present invention offers an alternative, more economical source. It also offers the opportunity of cancelling out specificity by manipulating the four chains of the tetramer separately.

A.2 General Structure Characteristics

The basic immunoglobulin structural unit in vertebrate systems is now well understood (Edelman, G.M., Ann. N.Y. Acad. Sci., 190: 5 (1971)). The units are composed of two identical light polypeptide chains of molecular weight approximately 23,000 daltons, and two identical heavy chains of molecular weight 53,000 - 70,000. The four chains are joined by disulfide bonds in a "Y" configuration wherein the light chains bracket the heavy chains starting at the mouth of the Y and continuing through the divergent region as shown in figure 1. The "branch" portion, as there indicated, is designated the Fab region. Heavy chains are classified as gamma, mu, alpha, delta, or epsilon, with some subclasses among them, and the nature of this chain, as it has a long constant region, determines the "class" of the antibody as IgG, IgM, IgA, IgD, or IgE. Light chains are classified as either kappa or lambda. Each heavy chain class can be prepared with either kappa or lambda light chain. The light and heavy chains are covalently bonded to each other, and the "tail" portions of the two heavy chains are bonded to each other by covalent disulfide linkages when the immunoglobulins are generated either by hybridomas or by B cells. However, if non-covalent association of the chains can be effected in the correct geometry, the aggregate will still be capable of reaction

with antigen, or of utility as a protein supplement as a non-specific immunoglobulin.

5 The amino acid sequence runs from the N-terminal end at the top of the Y to the C-terminal end at the bottom of each chain. At the N-terminal end is a variable region which is specific for the antigen which elicited it, and is approximately 100 amino acids in length, there being slight variations between light and heavy chain and from antibody to antibody. The variable region is linked in
10 each chain to a constant region which extends the remaining length of the chain. Linkage is seen, at the genomic level, as occurring through a linking sequence known currently as the "J" region in the light chain gene, which encodes about 12 amino acids, and as a combination of "D" region and "J" region in the heavy chain gene,
15 which together encode approximately 25 amino acids.

The remaining portions of the chain are referred to as constant regions and within a particular class do not to vary with the specificity of the antibody (i.e., the antigen eliciting it).

20 As stated above, there are five known major classes of constant regions which determine the class of the immunoglobulin molecule (IgG, IgM, IgA, IgD, and IgE corresponding to γ , μ , α , δ , and ϵ heavy chain constant regions). The constant region or class
25 determines subsequent effector function of the antibody, including activation of complement (Kabat, E.A., Structural Concepts in Immunology and Immunochemistry, 2nd Ed., p. 413-436, Holt, Rinehart, Winston (1976)), and other cellular responses (Andrews, D.W., et al., Clinical Immunobiology pp 1-18, W.B. Sanders (1980); Kohl,
30 S., et al., Immunology, 48: 187 (1983)); while the variable region determines the antigen with which it will react.

B. Recombinant DNA Technology

Recombinant DNA technology has reached sufficient sophistication

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that it includes a repertoire of techniques for cloning and expression of gene sequences. Various DNA sequences can be recombined with some facility, creating new DNA entities capable of producing heterologous protein product in transformed microbes and cell cultures. The general means and methods for the in vitro ligation of various blunt ended or "sticky" ended fragments of DNA, for producing expression vectors, and for transforming organisms are now in hand.

DNA recombination of the essential elements (i.e., an origin of replication, one or more phenotypic selection characteristics, expression control sequence, heterologous gene insert and remainder vector) generally is performed outside the host cell. The resulting recombinant replicable expression vector, or plasmid, is introduced into cells by transformation and large quantities of the recombinant vehicle is obtained by growing the transformant. Where the gene is properly inserted with reference to portions which govern the transcription and translation of the encoded DNA message, the resulting expression vector is useful to produce the polypeptide sequence for which the inserted gene codes, a process referred to as "expression." The resulting product may be obtained by lysis, if necessary, of the host cell and recovery of the product by appropriate purifications from other proteins.

In practice, the use of recombinant DNA technology can express entirely heterologous polypeptides--so-called direct expression--or alternatively may express a heterologous polypeptide fused to a portion of the amino acid sequence of a homologous polypeptide. In the latter cases, the intended bioactive product is sometimes rendered bioinactive within the fused, homologous/heterologous polypeptide until it is cleaved in an extracellular environment.

The art of maintaining cell or tissue cultures as well as microbial systems for studying genetics and cell physiology is well

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established. Means and methods are available for maintaining permanent cell lines, prepared by successive serial transfers from isolated cells. For use in research, such cell lines are maintained on a solid support in liquid medium, or by growth in suspension containing support nutriment. Scale-up for large preparations seems to pose only mechanical problems.

Summary of the Invention

The invention relates to antibodies and to non-specific immunoglobulins (NSIs) formed by recombinant techniques using suitable host cell cultures. These antibodies and NSIs can be readily prepared in pure "monoclonal" form. They can be manipulated at the genomic level to produce chimeras of variants which draw their homology from species which differ from each other. They can also be manipulated at the protein level, since all four chains do not need to be produced by the same cell. Thus, there are a number of "types" of immunoglobulins encompassed by the invention.

First, immunoglobulins, particularly antibodies, are produced using recombinant techniques which mimic the amino acid sequence of naturally occurring antibodies produced by either mammalian B cells in situ, or by B cells fused with suitable immortalizing tumor lines, i.e., hybridomas. Second, the methods of this invention produce, and the invention is directed to, immunoglobulins which comprise polypeptides not hitherto found associated with each other in nature. Such reassembly is particularly useful in producing "hybrid" antibodies capable of binding more than one antigen; and in producing "composite" immunoglobulins wherein heavy and light chains of different origins essentially damp out specificity. Third, by genetic manipulation, "chimeric" antibodies can be formed wherein, for example, the variable regions correspond to the amino acid sequence from one mammalian model system, whereas the constant region mimics the amino acid sequence of another. Again, the derivation of these two mimicked sequences may be from different

species. Fourth, also by genetic manipulation, "altered" antibodies with improved specificity and other characteristics can be formed.

Two other types of immunoglobulin-like moieties may be produced: "univalent" antibodies, which are useful as homing carriers to target tissues, and "Fab proteins" which include only the "Fab" region of an immunoglobulin molecule i.e., the branches of the "Y". These univalent antibodies and Fab fragments may also be "mammalian" i.e., mimic mammalian amino acid sequences; novel assemblies of mammalian chains, or chimeric, where for example, the constant and variable sequence patterns may be of different origin. Finally, either the light chain or heavy chain alone, or portions thereof, produced by recombinant techniques are included in the invention and may be mammalian or chimeric.

In other aspects, the invention is directed to DNA which encodes the aforementioned NSIs, antibodies, and portions thereof, as well as expression vectors or plasmids capable of effecting the production of such immunoglobulins in suitable host cells. It includes the host cells and cell cultures which result from transformation with these vectors. Finally, the invention is directed to methods of producing these NSIs and antibodies, and the DNA sequences, plasmids, and transformed cells intermediate to them.

Brief Description of the Drawings

Figure 1 is a representation of the general structure of immunoglobulins.

Figure 2 shows the detailed sequence of the cDNA insert of pK1764 which encodes kappa anti CEA chain.

Figure 3 shows the coding sequence of the fragment shown in Figure 2, along with the corresponding amino acid sequence.

Figure 4 shows the combined detailed sequence of the cDNA inserts of pY298 and pY11 which encode gamma anti CEA chain.

5 Figure 5 shows the corresponding amino acid sequence encoded by the fragment in Figure 4.

Figures 6 and 7 outline the construction of expression vectors for kappa and gamma anti-CEA chains respectively.

10 Figures 8A, 8B, and 8C show the results of sizing gels run on extracts of *E. coli* expressing the genes for gamma chain, kappa chain, and both kappa and gamma chains respectively.

15 Figure 9 shows the results of western blots of extracts of cells transformed as those in Figures 8.

Figure 10 shows a standard curve for ELISA assay of anti CEA activity.

20 Figures 11 and 12 show the construction of a plasmid for expression of the gene encoding a chimeric heavy chain.

Figure 13 shows the construction of a plasmid for expression of the gene encoding the Fab region of heavy chain.

25 Detailed Description

A. Definitions

30 As used herein, "antibodies" refers to tetramers or aggregates thereof which have specific immunoreactive activity, comprising light and heavy chains usually aggregated in the "Y" configuration of Figure 1, with or without covalent linkage between them; "immunoglobulins" refers to such assemblies whether or not specific immunoreactive activity is a property. "Non-specific

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immunoglobulin" ("NSI") means those immunoglobulins which do not possess specificity--i.e., those which are not antibodies.

5 "Mammalian antibodies" refers to antibodies wherein the amino acid sequences of the chains are homologous with those sequences found in antibodies produced by mammalian systems, either in situ, or in hybridomas. These antibodies mimic antibodies which are otherwise capable of being generated, although in impure form, in these traditional systems.

10 "Hybrid antibodies" refers to antibodies wherein chains are separately homologous with referenced mammalian antibody chains and represent novel assemblies of them, so that two different antigens are precipitable by the tetramer. In hybrid antibodies, one pair of heavy and light chain is homologous to antibodies raised against one
15 antigen, while the other pair of heavy and light chain is homologous to those raised against another antigen. This results in the property of "divalence" i.e., ability to bind two antigens simultaneously. Such hybrids may, of course, also be formed using
20 chimeric chains, as set forth below.

"Composite" immunoglobulins means those wherein the heavy and light chains mimic those of different species origins or specificities, and the resultant is thus likely to be a non-specific
25 immunoglobulin (NSI), i.e.--lacking in antibody character.

"Chimeric antibodies" refers to those antibodies wherein one portion of each of the amino acid sequences of heavy and light chains is homologous to corresponding sequences in antibodies
30 derived from a particular species or belonging to a particular class, while the remaining segment of the chains is homologous to corresponding sequences in another. Typically, in these chimeric antibodies, the variable region of both light and heavy chains mimics the variable regions of antibodies derived from one species

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of mammals, while the constant portions are homologous to the sequences in antibodies derived from another. One clear advantage to such chimeric forms is that, for example, the variable regions can conveniently be derived from presently known sources using readily available hybridomas or B cells from non human host organisms in combination with constant regions derived from, for example, human cell preparations. While the variable region has the advantage of ease of preparation, and the specificity is not affected by its source, the constant region being human, is less likely to elicit an immune response from a human subject when the antibodies are injected than would the constant region from a non-human source.

However, the definition is not limited to this particular example. It includes any antibody in which either or both of the heavy or light chains are composed of combinations of sequences mimicking the sequences in antibodies of different sources, whether these sources be differing classes, differing antigen responses, or differing species of origin and whether or not the fusion point is at the variable/constant boundary. Thus, it is possible to produce antibodies in which neither the constant nor the variable region mimic known antibody sequences. It then becomes possible, for example, to construct antibodies whose variable region has a higher specific affinity for a particular antigen, or whose constant region can elicit enhanced complement fixation or to make other improvements in properties possessed by a particular constant region.

"Altered antibodies" means antibodies wherein the amino acid sequence has been varied from that of a mammalian or other vertebrate antibody. Because of the relevance of recombinant DNA techniques to this invention, one need not be confined to the sequences of amino acids found in natural antibodies; antibodies can be redesigned to obtain desired characteristics. The possible variations are many and range from the changing of just one or a few

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amino acids to the complete redesign of, for example, the constant region. Changes in the constant region will, in general, be made in order to improve the cellular process characteristics, such as complement fixation, interaction with membranes, and other effector functions. Changes in the variable region will be made in order to improve the antigen binding characteristics. The antibody can also be engineered so as to aid the specific delivery of a toxic agent according to the "magic bullet" concept. Alterations, can be made by standard recombinant techniques and also by oligonucleotide-directed mutagenesis techniques (Dalbadie-McFarland, et al Proc. Natl. Acad. Sci. (USA), 79:6409 (1982)).

"Univalent antibodies" refers to aggregations which comprise a heavy chain/light chain dimer bound to the Fc (or stem) region of a second heavy chain. Such antibodies are specific for antigen, but have the additional desirable property of targeting tissues with specific antigenic surfaces, without causing its antigenic effectiveness to be impaired—i.e., there is no antigenic modulation. This phenomenon and the property of univalent antibodies in this regard is set forth in Glennie, M.J., et al., Nature, 295: 712 (1982). Univalent antibodies have heretofore been formed by proteolysis.

"Fab" region refers to those portions of the chains which are roughly equivalent, or analogous, to the sequences which comprise the Y branch portions of the heavy chain and to the light chain in its entirety, and which collectively (in aggregates) have been shown to exhibit antibody activity. "[Fab protein", which protein is one of the aspects of the invention, includes aggregates of one heavy and one light chain (commonly known as Fab'), as well as tetramers which correspond to the two branch segments of the antibody Y, (commonly known as F(ab)₂), whether any of the above are covalently or non-covalently aggregated, so long as the aggregation is capable of selectively reacting with a particular antigen or

antigen family. Fab antibodies have, as have univalent ones, been formed heretofore by proteolysis, and share the property of not eliciting antigen modulation on target tissues. However, as they lack the "effector" Fc portion they cannot effect, for example, lysis of the target cell by macrophages.

"Fab protein" has similar subsets according to the definition of the present invention as does the general term "antibodies" or "immunoglobulins". Thus, "mammalian" Fab protein, "hybrid" Fab protein "chimeric" Fab and "altered" Fab protein are defined analogously to the corresponding definitions set forth in the previous paragraphs for the various types of antibodies.

Individual heavy or light chains may of course be "mammalian", "chimeric" or "altered" in accordance with the above. As will become apparent from the detailed description of the invention, it is possible, using the techniques disclosed to prepare other combinations of the four-peptide chain aggregates, besides those specifically defined, such as hybrid antibodies containing chimeric light and mammalian heavy chains, hybrid Fab proteins containing chimeric Fab proteins of heavy chains associated with mammalian light chains, and so forth.

"Expression vector" includes vectors which are capable of expressing DNA sequences contained therein, i.e., the coding sequences are operably linked to other sequences capable of effecting their expression. It is implied, although not always explicitly stated, that these expression vectors must be replicable in the host organisms either as episomes or as an integral part of the chromosomal DNA. Clearly a lack of replicability would render them effectively inoperable. A useful, but not a necessary, element of an effective expression vector is a marker encoding sequence -- i.e. a sequence encoding a protein which results in a phenotypic property (e.g. tetracycline resistance) of the cells

containing the protein which permits those cells to be readily identified. In sum, "expression vector" is given a functional definition, and any DNA sequence which is capable of effecting expression of a specified contained DNA code is included in this term, as it is applied to the specified sequence. As at present, such vectors are frequently in the form of plasmids, thus "plasmid" and "expression vector" are often used interchangeably. However, the invention is intended to include such other forms of expression vectors which serve equivalent functions and which may, from time to time become known in the art.

"Recombinant host cells" refers to cells which have been transformed with vectors constructed using recombinant DNA techniques. As defined herein, the antibody or modification thereof produced by a recombinant host cell is by virtue of this transformation, rather than in such lesser amounts, or more commonly, in such less than detectable amounts, as would be produced by the untransformed host.

In descriptions of processes for isolation of antibodies from recombinant hosts, the terms "cell" and "cell culture" are used interchangeably to denote the source of antibody unless it is clearly specified otherwise. In other words, recovery of antibody from the "cells" may mean either from spun down whole cells, or from the cell culture containing both the medium and the suspended cells.

B. Host Cell Cultures and Vectors

The vectors and methods disclosed herein are suitable for use in host cells over a wide range of prokaryotic and eukaryotic organisms.

In general, of course, prokaryotes are preferred for cloning of DNA sequences in constructing the vectors useful in the invention. For example, E. coli K12 strain 294 (ATCC No. 31446) is particularly useful. Other microbial strains which may be used include E. coli strains such as E. coli B, and E. coli X1776 (ATCC No. 31537).

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baker's yeast is the most commonly used among eukaryotic microorganisms, although a number of other strains are commonly available. For expression in Saccharomyces, the plasmid YRp7, for example, (Stinchcomb, et al, Nature, 282: 39 (1979); Kingsman et al, Gene, 7: 141 (1979); Tschemper, et al, Gene, 10: 157 (1980)) is commonly used. This plasmid already contains the trp1 gene which provides a selection marker for a mutant strain of yeast lacking the ability to grow in tryptophan, for example ATCC No. 44076 or PEP4-1 (Jones, Genetics, 85: 12 (1977)). The presence of the trp1 lesion as a characteristic of the yeast host cell genome then provides an effective environment for detecting transformation by growth in the absence of tryptophan.

Suitable promoting sequences in yeast vectors include the promoters for 3-phosphoglycerate kinase (Hitzeman, et al., J. Biol. Chem., 255: 2073 (1980)) or other glycolytic enzymes (Hess, et al, J. Adv. Enzyme Reg., 7: 149 (1968); Holland, et al, Biochemistry, 17: 4900 (1978)), such as enolase, glyceraldehyde-3-phosphate dehydrogenase, hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate mutase, pyruvate kinase, triosephosphate isomerase, phosphoglucose isomerase, and glucokinase. In constructing suitable expression plasmids, the termination sequences associated with these genes are also ligated into the expression vector 3' of the sequence desired to be expressed to provide polyadenylation of the mRNA and termination. Other promoters, which have the additional advantage of transcription controlled by growth conditions are the promoter regions for alcohol dehydrogenase 2, isocytochrome C, acid phosphatase, degradative enzymes associated with nitrogen metabolism, and the aforementioned glyceraldehyde-3-phosphate dehydrogenase, and enzymes responsible for maltose and galactose utilization (Holland, *ibid.*). Any plasmid vector containing yeast-compatible promoter, origin of replication and termination sequences is suitable.

In addition to microorganisms, cultures of cells derived from multicellular organisms may also be used as hosts. In principle, any such cell culture is workable, whether from vertebrate or invertebrate culture. However interest has been greatest in vertebrate cells, and propagation of vertebrate cells in culture (tissue culture) has become a routine procedure in recent years (Tissue Culture, Academic Press, Kruse and Patterson, editors (1973)). Examples of such useful host cell lines are VERO and HeLa cells, Chinese hamster ovary (CHO) cell lines, and WI38, BHK, COS-7 and MDCK cell lines. Expression vectors for such cells ordinarily include (if necessary) an origin of replication, a promoter located in front of the gene to be expressed, along with any necessary ribosome binding sites, RNA splice sites, polyadenylation site, and transcriptional terminator sequences.

For use in mammalian cells, the control functions on the expression vectors are often provided by viral material. For example, commonly used promoters are derived from polyoma, Adenovirus 2, and most frequently Simian Virus 40 (SV40). The early and late promoters of SV40 virus are particularly useful because both are obtained easily from the virus as a fragment which also contains the SV40 viral origin of replication (Fiers, et al, Nature, 273: 113 (1978)) incorporated herein by reference. Smaller or larger SV40 fragments may also be used, provided there is included the approximately 250 bp sequence extending from the Hind III site toward the Bgl I site located in the viral origin of replication. Further, it is also possible, and often desirable, to utilize promoter or control sequences normally associated with the desired gene sequence, provided such control sequences are compatible with the host cell systems.

An origin of replication may be provided either by construction of the vector to include an exogenous origin, such as may be derived from SV40 or other viral (e.g. Polyoma, Adeno, VSV, BPV, etc.)

source, or may be provided by the host cell chromosomal replication mechanism. If the vector is integrated into the host cell chromosome, the latter is often sufficient.

It will be understood that this invention, although described herein in terms of a preferred embodiment, should not be construed as limited to those host cells, vectors and expression systems exemplified.

C. Methods Employed

C.1 Transformation:

If cells without formidable cell wall barriers are used as host cells, transfection is carried out by the calcium phosphate precipitation method as described by Graham and Van der Eb, Virology, 52: 546 (1978). However, other methods for introducing DNA into cells such as by nuclear injection or by protoplast fusion may also be used.

If prokaryotic cells or cells which contain substantial cell wall constructions are used, the preferred method of transfection is calcium treatment using calcium chloride as described by Cohen, F.N. et al Proc. Natl. Acad. Sci. (USA), 69: 2110 (1972).

C.2 Vector Construction

Construction of suitable vectors containing the desired coding and control sequences employ standard ligation techniques. Isolated plasmids or DNA fragments are cleaved, tailored, and religated in the form desired to form the plasmids required. The methods employed are not dependent on the DNA source, or intended host.

Cleavage is performed by treating with restriction enzyme (or enzymes) in suitable buffer. In general, about 1 μ g plasmid or DNA fragments is used with about 1 unit of enzyme in about 20 μ l of buffer solution. (Appropriate buffers and substrate amounts for

wherein the heavy and light chains mimic the amino acid sequences of an antibody otherwise produced by a mature mammalian B lymphocyte either in situ or when fused with an immortalized cell as part of a hybridoma culture. In outline, these antibodies are produced as follows:

Messenger RNA coding for heavy or light chain is isolated from a suitable source, either mature B cells or a hybridoma culture, employing standard techniques of RNA isolation, and the use of oligo-dT cellulose chromatography to segregate the poly-A mRNA. The poly-A mRNA may, further, be fractionated to obtain sequences of sufficient size to code for the amino acid sequences in the light or heavy chain of the desired antibody as the case may be.

A cDNA library is then prepared from the mixture of mRNA using a suitable primer, preferably a nucleic acid sequence which is characteristic of the desired cDNA. Such a primer may be hypothesized and synthesized based on the amino acid sequence of the antibody if the sequence is known. In the alternative cDNA from unfractionated poly-A mRNA from a cell line producing the desired antibody or poly-dT may also be used. The resulting cDNA is optionally size fractionated on polyacrylamide gel and then extended with, for example, dC residues for annealing with pBR322 or other suitable cloning vector which has been cleaved by a suitable restriction enzyme, such as Pst I, and extended with dG residues. Alternative means of forming cloning vectors containing the cDNA using other tails and other cloning vector remainder may, of course, also be used but the foregoing is a standard and preferable choice. A suitable host cell strain, typically *E. coli*, is transformed with the annealed cloning vectors, and the successful transformants identified by means of, for example, tetracycline resistance or other phenotypic characteristic residing on the cloning vector plasmid.

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- Successful transformants are picked and transferred to microtiter dishes or other support for further growth and preservation. Nitrocellulose filter imprints of these growing cultures are then probed with suitable nucleotide sequences
- 5 containing bases known to be complementary to desired sequences in the cDNA. Several types of probe may be used, preferably synthetic single stranded DNA sequences labeled by kinasing with ATP³². The cells fixed to the nitrocellulose filter are lysed, the DNA denatured, and then fixed before reaction with kinased probe.
- 10 Clones which successfully hybridize are detected by contact with a photoplate, then plasmids from the growing colonies isolated and sequenced by means known in the art to verify that the desired portions of the gene are present.
- 15 The desired gene fragments are excised and tailored to assure appropriate reading frame with the control segments when inserted into suitable expression vectors. Typically, nucleotides are added to the 5' end to include a start signal and a suitably positioned restriction endonuclease site.
- 20 The tailored gene sequence is then positioned in a vector which contains a promoter in reading frame with the gene and compatible with the proposed host cell. A number of plasmids such as those described in U.S. Pat. Appln. Ser. Nos. 307473; 291892; and 305657
- 25 (EPO Publ. Nos. 0036776; 0048970 and 0051873) have been described which already contain the appropriate promoters, control sequences, ribosome binding sites, and transcription termination sites, as well as convenient markers.
- 30 In the present invention, the gene coding for the light chain and that coding for the heavy chain are recovered separately by the procedures outlined above. Thus they may be inserted into separate expression plasmids, or together in the same plasmid, so long as each is under suitable promoter and translation control.
- 35

The expression vectors constructed above are then used to transform suitable cells. The light and heavy chains may be transformed into separate cell cultures, either of the same or of differing species; separate plasmids for light and heavy chain may be used to co-transform a single cell culture, or, finally, a single expression plasmid containing both genes and capable of expressing the genes for both light and heavy chain may be transformed into a single cell culture.

Regardless of which of the three foregoing options is chosen, the cells are grown under conditions appropriate to the production of the desired protein. Such conditions are primarily mandated by the type of promoter and control systems used in the expression vector, rather than by the nature of the desired protein. The protein thus produced is then recovered from the cell culture by methods known in the art, but choice of which is necessarily dependent on the form in which the protein is expressed. For example, it is common for mature heterologous proteins expressed in E. coli to be deposited within the cells as insoluble particles which require cell lysis and solubilization in denaturant to permit recovery. On the other hand, proteins under proper synthesis circumstances, in yeast and bacterial strains, can be secreted into the medium (yeast and gram positive bacteria) or into the periplasmic space (gram negative bacteria) allowing recovery by less drastic procedures. Tissue culture cells as hosts also appear, in general, to permit reasonably facile recovery of heterologous proteins.

When heavy and light chain are coexpressed in the same host, the isolation procedure is designed so as to recover reconstituted antibody. This can be accomplished in vitro as described below, or might be possible in vivo in a microorganism which secretes the IgG chains out of the reducing environment of the cytoplasm. A more detailed description is given in D.2, below.

D.2 Chain Recombination Techniques

The ability of the method of the invention to produce heavy and light chains or portions thereof, in isolation from each other offers the opportunity to obtain unique and unprecedented assemblies of immunoglobulins, Fab regions, and univalent antibodies. Such preparations require the use of techniques to reassemble isolated chains. Such means are known in the art, and it is, thus, appropriate to review them here.

While single chain disulfide bond containing proteins have been reduced and reoxidized to regenerate in high yield native structure and activity (Freedman, R.B., et al. In Enzymology of Post Translational Modification of Proteins, I: 157-212 (1980) Academic Press, NY.), proteins which consist of discontinuous polypeptide chains held together by disulfide bonds are more difficult to reconstruct in vitro after reductive cleavage. Insulin, a cameo case, has received much experimental attention over the years, and can now be reconstructed so efficiently that an industrial process has been built around it (Chance, R.E., et al., In Peptides: Proceedings of the Seventh Annual American Peptide Symposium (Rich, D.H. and Gross, E., eds.) 721-728, Pierce Chemical Co., Rockford, IL. (1981)).

Immunoglobulin has proved a more difficult problem than insulin. The tetramer is stabilized intra and intermolecularly by 15 or more disulfide bonds. It has been possible to recombine heavy and light chains, disrupted by cleavage of only the interchain disulfides, to regain antibody activity even without restoration of the inter-chain disulfides (Edelmann, G.M., et al., Proc. Natl. Acad. Sci. (USA) 50: 753 (1963)). In addition, active fragments of IgG formed by proteolysis (Fab fragments of ~50,000 MW) can be split into their fully reduced heavy chain and light chain components and fairly efficiently reconstructed to give active antibody (Haber, E., Proc. Natl. Acad. Sci. (USA) 52: 1099 (1964); Whitney, P.L.,

et al., Proc. Natl. Acad. Sci. (USA) 53: 524 (1965)). Attempts to reconstitute active antibody from fully reduced native IgG have been largely unsuccessful, presumably due to insolubility of the reduced chains and of side products or intermediates in the refolding pathway (see discussion in Freedman, M.H., et al., J. Biol. Chem. 241: 5225 (1966)). If, however, the immunoglobulin is randomly modified by polyalanylation of its lysines before complete reduction, the separated chains have the ability to recover antigen-combining activity upon reoxidation (ibid).

A particularly suitable method for immunoglobulin reconstitution is derivable from the now classical insulin recombination studies, wherein starting material was prepared by oxidative sulfitolysis, thus generating thiol-labile S-sulfonate groups at all cysteines in the protein, non-reductively breaking disulfides (Chance et al. (supra)). Oxidative sulfitolysis is a mild disulfide cleavage reaction (Means, G.E., et al., Chemical Modification of Proteins, Holden-Day, San Francisco (1971)) which is sometimes more gentle than reduction, and which generates derivatives which are stable until exposed to mild reducing agent at which time disulfide reformation can occur via thiol-disulfide interchange. In the present invention the heavy and light chain S-sulfonates generated by oxidative sulfitolysis were reconstituted utilizing both air oxidation and thiol-disulfide interchange to drive disulfide bond formation. The general procedure is set forth in detail in U.S. Serial No. 452,187, filed Dec. 22, 1982 (EPO Appln. No. 83.307840.5), incorporated herein by reference.

D.3 Variants Permitted by Recombinant Technology

Using the techniques described in paragraphs D.1 and D.2, additional operations which were utilized to gain efficient production of mammalian antibody can be varied in quite straightforward and simple ways to produce a great variety of

modifications of this basic antibody form. These variations are inherent in the use of recombinant technology, which permits modification at a genetic level of amino acid sequences in normally encountered mammalian immunoglobulin chains, and the great power of this approach lies in its ability to achieve these variations, as well as in its potential for economic and specific production of desired scarce, and often contaminated, molecules. The variations also inhere in the ability to isolate production of individual chains, and thus create novel assemblies.

Briefly, since genetic manipulations permit reconstruction of genomic material in the process of construction of expression vectors, such reconstruction can be manipulated to produce new coding sequences for the components of "natural" antibodies or immunoglobulins. As discussed in further detail below, the coding sequence for a mammalian heavy chain may not be derived entirely from a single source or single species, but portions of a sequence can be recovered by the techniques described in D.1 from differing pools of mRNA, such as murine-murine hybridomas, human-murine hybridomas, or B cells differentiated in response to a series of antigen challenges. The desired portions of the sequences in each case can be recovered using the probe and analysis techniques described in D.1, and recombined in an expression vector using the same ligation procedures as would be employed for portions of the same model sequence. Such chimeric chains can be constructed of any desired length; hence, for example, a complete heavy chain can be constructed, or only sequence for the Fab region thereof.

The additional area of flexibility which arises from the use of recombinant techniques results from the power to produce heavy and light chains or fragments thereof in separate cultures or of unique combinations of heavy and light chain in the same culture, and to prevent reconstitution of the antibody or immunoglobulin aggregation until the suitable components are assembled. Thus, while normal

antibody production results automatically in the formation of "mammalian antibodies" because the light and heavy chain portions are constructed in response to a particular determinant in the same cell, the methods of the present invention present the opportunity to assemble entirely new mixtures. Somewhat limited quantities of "hybrid" antibodies have been produced by "quadromas" i.e., fusions of two hybridoma cell cultures which permit random assemblies of the heavy and light chains so produced.

The present invention permits a more controlled assembly of desired chains, either by mixing the desired chains in vitro, or by transforming the same culture with the coding sequences for the desired chains.

D.4 Composite Immunoglobulins

The foregoing procedure, which describes in detail the recombinant production of mammalian antibodies is employed with some modifications to construct the remaining types of antibodies or NSIs encompassed by the present invention. To prepare the particular embodiment of composite non-specific immunoglobulin wherein the homology of the chains corresponds to the sequences of immunoglobulins of different specificities, it is of course, only necessary to prepare the heavy and light chains in separate cultures and reassemble them as desired.

For example, in order to make an anti-CEA light chain/anti-hepatitis heavy chain composite antibody, a suitable source for the mRNA used as a template for the light chain clone would comprise, for instance, the anti CEA producing cell line of paragraph E.1. The mRNA corresponding to heavy chain would be derived from B cells raised in response to hepatitis infection or from hybridoma in which the B cell was of this origin. It is clear that such composites can be assembled using the methods of the invention almost at will, and are limited only by available sources of mRNA suitable for use as

to ligate the variable portions of the mouse gene to the constant regions of the human gene for each of the two chains. The chimeric chains are produced as set forth in D.1, aggregated as set forth in D.2 and used in the same manner as the non-chimeric forms. Of course, any splice point in the chains can be chosen.

D.7 Altered Antibodies

Altered antibodies present, in essence, an extension of chimeric ones. Again, the techniques of D.1 and D.2 are applicable; however, rather than splicing portions of the chain(s), suitable amino acid alterations, deletions or additions are made using available techniques such as mutagenesis (supra). For example, genes which encode antibodies having diminished complement fixation properties, or which have enhanced metal binding capacities are prepared using such techniques. The latter type may, for example, take advantage of the known gene sequence encoding metallothionein II (Karin, M., et al., Nature, 299: 797 (1982)). The chelating properties of this molecular fragment are useful in carrying heavy metals to tumor sites as an aid in tumor imaging (Scheinberg, D.A., et al., Science, 215: 19 (1982)).

D.8 Univalent Antibodies

In another preferred embodiment, antibodies are formed which comprise one heavy and light chain pair coupled with the Fc region of a third (heavy) chain. These antibodies have a particularly useful property. They can, like ordinary antibodies, be used to target antigenic surfaces of tissues, such as tumors, but, unlike ordinary antibodies, they do not cause the antigenic surfaces of the target tissue to retreat and become non-receptive. Ordinary antibody use results in aggregation and subsequent inactivation, for several hours, of such surface antigens.

The method of construction of univalent antibodies is a straightforward application of the invention. The gene for heavy

chain of the desired Fc region is cleaved by restriction enzymes, and only that portion coding for the desired Fc region expressed. This portion is then bound using the technique of D.2 to separately produced heavy chain the desired pairs separated from heavy/heavy and Fc/Fc combinations, and separately produced light chain added. Pre-binding of the two heavy chain portions thus diminishes the probability of formation of ordinary antibody.

D.9 Fab Protein

Similarly, it is not necessary to include the entire gene for the heavy chain portion. All of the aforementioned variations can be superimposed on a procedure for Fab protein production and the overall procedure differs only in that that portion of the heavy chain coding for the amino terminal 220 amino acids is employed in the appropriate expression vector.

E. Specific Examples of Preferred Embodiments

The invention has been described above in general terms and there follow several specific examples of embodiments which set forth details of experimental procedure in producing the desired antibodies. Example E.1 sets forth the general procedure for preparing anti CEA antibody components, i.e. for a "mammalian antibody". Example E.3 sets forth the procedure for reconstitution and thus is applicable to preparation of mammalian, composite, hybrid and chimeric immunoglobulins, and Fab proteins and univalent antibodies. Example E.4 sets forth the procedure for tailoring the heavy or light chain so that the variable and constant regions may be derived from different sources. Example E.5 sets forth the method of obtaining a shortened heavy chain genome which permits the production of the Fab regions and, in an analogous manner, Fc region.

The examples set forth below are included for illustrative purposes and do not limit the scope of the invention.

E.1 Construction of Expression Vectors for Murine anti-CEA
Antibody Chains and Peptide Synthesis

Carcinoembryonic antigen (CEA) is associated with the surface of certain tumor cells of human origin (Gold, P., et al., J. Exp. Med., 122: 467 (1965)). Antibodies which bind to CEA (anti-CEA anti-
5 bodies) are useful in early detection of these tumors (Van Nagell, T.R., et al., Cancer Res. 40: 502 (1980)), and have the potential for use in treatment of those human tumors which appear to support CEA at their surfaces. A mouse hybridoma cell line which secretes
10 anti-CEA antibodies of the Ig_Y class, CEA.66-E3, has been prepared as described by Wagener, C. et al., J. Immunol. 130, 2308 (1983) which is incorporated herein by reference, and was used as mRNA source. The production of anti CEA antibodies by this cell line was determined. The N-terminal sequences of the antibodies produced by these cells
15 was compared with those of monoclonal anti CEA as follows. Purified IgG was treated with PCAse (Podell, D.N., et al., Biochem. Biophys. Res. Commun. 81: 176 (1978)), and then dissociated in 6M guanidine hydrochloride, 10 mM 2-mercaptoethanol (1.0 mg of immunoglobulin, 5 min, 100°C water bath). The dissociated chains were separated on a
20 Waters Associates alkyl phenyl column using a linear gradient from 100 percent A (0.1 percent TFA-water) to 90 percent B (TFA/H₂O/MeCN 0.1/9.9/90) at a flow rate of 0.8 ml/min. Three major peaks were eluted and analyzed on SDS gels by silver staining. The first two peaks were pure light chain (MW 25,000 daltons), the third peak
25 showed a (7:3) mixture of heavy and light chain. 1.2 nmoles of light chain were sequenced by the method of Shively, J.E., Methods in Enzymology, 79: 31 (1981), with an NH₂-terminal yield of 0.4 nmoles. A mixture of heavy and light chains (3 nmoles) was also sequenced, and sequence of light chain was deducted from the double
30 sequence to yield the sequence of the heavy chain.

In the description which follows, isolation and expression of the genes for the heavy and light chains for anti CEA antibody produced by CEA.66-E3 are described. As the constant regions of these chains

belong to the gamma and kappa families, respectively, "light chain" and "kappa chain", and "heavy chain" and "gamma chain", respectively, are used interchangeably below.

5

E.1.1 Isolation of Messenger RNA for Anti CEA Light and Heavy (Kappa and Gamma) Chains

Total RNA from CEA.66-E3 cells was extracted essentially as reported by Lynch et al, Virology, 98: 251 (1979). Cells were pelleted by centrifugation and approximately 1 g portions of pellet
10 resuspended in 10 ml of 10 mM NaCl, 10 mM Tris HCl (pH 7.4), 1.5 mM MgCl₂. The resuspended cells were lysed by addition of non-ionic detergent NP-40 to a final concentration of 1 percent, and nuclei removed by centrifugation. After addition of SDS (pH 7.4) to 1
15 percent final concentration, the supernatant was extracted twice with 3 ml portions of phenol (redistilled)/chloroform: isoamyl alcohol 25:1 at 4°C. The aqueous phase was made 0.2 M in NaCl and total RNA was precipitated by addition of two volumes of 100 percent ethanol and overnight storage at -20°C. After centrifugation, polyA
20 mRNA was purified from total RNA by oligo-dT cellulose chromatography as described by Aviv and Leder, Proc. Nat'l. Acad. Sci. (USA), 69: 1408 (1972). 142 µg of polyA mRNA was obtained from 1 g cells.

25

E.1.2 Preparation of E. coli Colony Library Containing Plasmids with Heavy and Light DNA Sequence Inserts

5 µg of the unfractionated polyA mRNA prepared in paragraph E.1.1 was used as template for oligo-dT primed preparation of double-stranded (ds) cDNA by standard procedures as described by
30 Goeddel et al., Nature 281: 544 (1979) and Wickens et al., J. Biol. Chem. 253: 2483 (1978) incorporated herein by reference. The cDNA was size fractionated by 6 percent polyacrylamide gel electrophoresis and 124 ng of ds cDNA greater than 600 base pairs in
35 length was recovered by electroelution. A 20 ng portion of ds cDNA was extended with deoxy C residues using terminal deoxynucleotidyl

transferase as described in Chang et al., Nature 275: 617 (1978) incorporated herein by reference, and annealed with 200 ng of the plasmid pBR322 (Bolivar et al., Gene 2: 95 (1977)) which had been cleaved with Pst I and tailed with deoxy G. Each annealed mixture was then transformed into E. coli K12 strain 294 (ATCC No. 31446). Approximately 8500 ampicillin sensitive, tetracycline resistant transformants were obtained.

E.1.3 Preparation of Synthetic Probes

The 14mer, 5' GGTGGGAAGATGGA 3' complementary to the coding sequence of constant region for mouse MOPC21 kappa chain which begins 25 basepairs 3' of the variable region DNA sequence was used as kappa chain probe. A 15 mer, 5' GACCAGGCATCCCAG 3', complementary to a coding sequence located 72 basepairs 3' of the variable region DNA sequence for mouse MOPC21 gamma chain was used to probe gamma chain gene.

Both probes were synthesized by the phosphotriester method described in German Offenlegungsschrift 2644432, incorporated herein by reference, and made radioactive by kinasing as follows: 250 ng of deoxyoligonucleotide were combined in 25 μ l of 60 mM Tris HCl (pH 8), 10 mM $MgCl_2$, 15 mM beta-mercaptoethanol, and 100 μ Ci (γ - ^{32}P) ATP (Amersham, 5000 Ci/mMole). 5 units of T4 polynucleotide kinase were added and the reaction was allowed to proceed at 37°C for 30 minutes and terminated by addition of EDTA to 20 mM.

E.1.4 Screening of Colony Library for Kappa or Gamma Chain Sequences

~2000 colonies prepared as described in paragraph E.1.2 were individually inoculated into wells of microtitre dishes containing LB (Miller, Experiments in Molecular Genetics, p. 431-3, Cold Spring Harbor Lab., Cold Spring Harbor, New York (1972)) + 5 μ g/ml tetracycline and stored at -20°C after addition of DMSO to 7

analysis demonstrated that a number of plasmid DNAs contained cDNA inserts large enough to encode full length kappa chain. The complete nucleotide sequence of the cDNA insert of one of these plasmids was determined by the dideoxynucleotide chain termination method as described by Smith, Methods Enzymol. 65, 560 (1980) incorporated herein by reference after subcloning restriction endonuclease cleavage fragments into M13 vectors (Messing et al., Nucleic Acids Research 9: 309 (1981)). Figure 2 shows the nucleotide sequence of the cDNA insert of pK17G4 and Figure 3 shows the gene sequence with the corresponding amino acid sequence. Thus, the entire coding region of mouse anti-CEA kappa chain was isolated on this one large DNA fragment. The amino acid sequence of kappa chain, deduced from the nucleotide sequence of the pK17G4 cDNA insert, corresponds perfectly with the first 23 N-terminal amino acids of mature mouse anti-CEA kappa chain as determined by amino acid sequence analysis of purified mouse anti-CEA kappa chain. The coding region of pK17G4 contains 27 basepairs or 9 amino acids of the presequence and 642 basepairs or 214 amino acids of the mature protein. The mature unglycosylated protein (MW 24,553) has a variable region of 119 amino acids, including the J1 joining region of 12 amino acids, and a constant region of 107 amino acids. After the stop codon behind amino acid 215 begins 212 basepairs of 3' untranslated sequence up to the polyA addition. The kappa chain probe used to identify pK17G4 hybridizes to nucleotides 374-388 (figure 2).

E.1.6 Characterization of Colonies which Hybridize to Gamma 1 DNA Probe

Plasmid DNA isolated from several transformants positive for hybridization with the heavy chain gamma 1 probe was subjected to Pst I restriction endonuclease analysis as described in E.1.5. Plasmid DNAs demonstrating the largest cDNA insert fragments were selected for further study. Nucleotide sequence coding for mouse heavy (gamma-1) chain, shows an NcoI restriction endonuclease

cleavage site near the junction between variable and constant region. Selected plasmid DNAs were digested with both PstI and NcoI and sized on polyacrylamide. This analysis allowed identification of a number of plasmid DNAs that contain NcoI restriction endonuclease sites, although none that demonstrate cDNA insert fragments large enough to encode the entire coding region of mouse anti-CEA heavy chain.

In one plasmid isolated, p γ 298 the cDNA insert of about 1300 bp contains sequence information for the 5' untranslated region, the signal sequence and the N-terminal portion of heavy chain. Because p γ 298 did not encode the C-terminal sequence for mouse anti-CEA gamma 1 chain, plasmid DNA was isolated from other colonies and screened with PstI and NcoI. The C-terminal region of the cDNA insert of p γ 11 was sequenced and shown to contain the stop codon, 3' untranslated sequence and that portion of the coding sequence missing from p γ 298.

Figure 4 presents the entire nucleotide sequence of mouse anti-CEA heavy chain (as determined by the dideoxynucleotide chain termination method of Smith, Methods Enzymol., 65: 560 (1980)) and Figure 5 includes the translated sequence.

The amino acid sequence of gamma 1 (heavy chain) deduced from the nucleotide sequence of the p γ 298 cDNA insert corresponds perfectly to the first 23 N-terminal amino acids of mature mouse anti-CEA gamma 1 chain as determined by amino acid sequence analysis of purified mouse anti-CEA gamma-1 chain. The coding region consists of 57 basepairs or 19 amino acids of presequences and 1346 basepairs or 447 amino acids of mature protein. The mature unglycosylated protein (MW 52,258) has a variable region of 135 amino acids, including a D region of 12 amino acids, and a J α joining region of 13 amino acids. The constant region is 324 amino acids. After the stop codon behind amino acid 447 begins 96 bp of

3' untranslated sequences up to the polyA addition. The probe used to identify py298 and py11 hybridized to nucleotides 528-542 (Figure 4).

5 E.1.7 Construction of a Plasmid For Direct Expression of Mouse Mature Anti-CEA Kappa Chain Gene, pKCEAtrp207-1*

Figure 6 illustrates the construction of pKCEAtrp207-1*

10 First, an intermediate plasmid pHGH207-1*, having a single trp promoter, was prepared as follows:

15 The plasmid pHGH 207 (described in U.S. Pat. Appl. Serial No. 307,473, filed Oct. 1, 1981 (EPO PublN. No. 0036776)) has a double lac promoter followed by the trp promoter, flanked by EcoR I sites and was used to prepare pHGH207-1. pHGH207 was digested with BamH I, followed by partial digestion with EcoR I. The largest fragment, which contains the entire trp promoter, was isolated and ligated to the largest EcoR I- BamH I fragment from pBR322, and the ligation
20 mixture used to transform E. coli 294. Tet^R Amp^R colonies were isolated, and most of them contained pHGH207-1. pHGH207-1* which lacks the EcoRI site between the amp^R gene and the trp promoter, was obtained by partial digestion of pHGH207-1 with EcoR I, filling
25 in the ends with Klenow and dNTPs, and religation.

30 5 µg of pHGH207-1* was digested with EcoRI, and the ends extended to blunt ends using 12 units of DNA Polymerase I in a 50 µl reaction containing 60 mM NaCl, 7 mM MgCl₂, 7 mM Tris HCl (pH 7.4) and 1 mM in each dNTP at 37°C for 1 hour, followed by extraction
35 with phenol/CHCl₃ and precipitation with ethanol. The precipitated DNA was digested with BamH I, and the large vector fragment (fragment 1) purified using 5 percent polyacrylamide gel electrophoresis, electroelution, phenol/CHCl₃ extraction and ethanol precipitation.

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The DNA was resuspended in 50 μ l of 10 mM Tris pH 8, 1 mM EDTA and treated with 500 units Bacterial Alkaline Phosphatase (BAP) for 30' at 65° followed by phenol/ CHCl_3 extraction and ethanol precipitation.

5 A DNA fragment containing part of the light chain sequence was prepared as follows: 7 μ g of pK1764 DNA was digested with Pst I and the kappa chain containing cDNA insert was isolated by 6 percent gel electrophoresis, and electroelution. After phenol/ CHCl_3 10 extraction, ethanol precipitation and resuspension in water, this fragment was digested with Ava II. The 333 bp Pst I-Ava II DNA fragment was isolated and purified from a 6 percent polyacrylamide gel.

15 A 15 nucleotide DNA primer was synthesized by the phosphotriester method G. O. 2,644,432 (supra) and has the following sequence:

Met Asp Ile Val Met
5' ATG GAC ATT GTT ATG 3'

20 The 5' methionine serves as the initiation codon. 500 ng of this primer was phosphorylated at the 5' end with 10 units T4 DNA kinase in 20 μ l reaction containing 0.5 mM ATP. ~200 ng of the Pst I-Ava II DNA fragment was mixed with the 20 μ l of the phosphorylated 25 primer, heated to 95°C for 3 minutes and quick frozen in a dry-ice ethanol bath. The denatured DNA solution was made 60mM NaCl, 7mM MgCl_2 , 7 mM Tris HCl (pH 7.4), 12 mM in each dNTP and 12 units DNA Polymerase I-Large Fragment was added. After 2 hours incubation at 30 37°C this primer repair reaction was phenol/ CHCl_3 extracted, ethanol precipitated, and digested to completion with Sau 3A. The reaction mixture was then electrophoresed on a 6 percent polyacrylamide gel and ~50 ng of the 182 basepair amino-terminal blunt-end to Sau 3A fragment (fragment 2) was obtained after 35 electroelution.

100 ng of fragment 1 (supra) and 50 ng of fragment 2 were combined in 20 μ l of 20 mM Tris HCl (pH 7.5), 10 mM $MgCl_2$, 10 mM DTT, 2.5 mM ATP and 1 unit of T4 DNA ligase. After overnight ligation at 14°C the reaction was transformed into E. coli K12 strain 294. Restriction endonuclease digestion of plasmid DNA from a number of ampicillin resistant transformants indicated the proper construction and DNA sequence analysis proved the desired nucleotide sequence through the initiation codon of this new plasmid, pKCEAInt1 (Figure 6).

The remainder of the coding sequence of the kappa light chain gene was prepared as follows:

The Pst I cDNA insert fragment from 7 μ g of K17G4 DNA was partially digested with Ava II and the Ava II cohesive ends were extended to blunt ends in a DNA Polymerase I large fragment reaction. Following 6 percent polyacrylamide gel electrophoresis the 686 basepair Pst I to blunt ended Ava II DNA fragment was isolated, purified and subjected to Hpa II restriction endonuclease digestion. The 497 basepair Hpa II to blunt ended Ava II DNA fragment (fragment 3) was isolated and purified after gel electrophoresis.

10 μ g of pKCEAInt1 DNA was digested with Ava I, extended with DNA polymerase I large fragment, and digested with Xba I. Both the large blunt ended Ava I to Xba I vector fragment and the small blunt ended Ava I to Xba I fragment were isolated and purified from a 6 percent polyacrylamide gel after electrophoresis. The large vector fragment (fragment 4) was treated with Bacterial Alkaline Phosphatase (BAP), and the small fragment was digested with Hpa II, electrophoresed on a 6 percent polyacrylamide and the 169 basepair Xba I-Hpa II DNA fragment (fragment 5) was purified. ~75 ng of fragment 4, ~50 ng of fragment 3 and ~50 ng of fragment 5 were combined in a T4 DNA ligase reaction and incubated overnight at 14°C.

-40-

and the reaction mixture transformed into E. coli K12 strain 294. Plasmid DNA from six ampicillin resistant transformants were analyzed by restriction endonuclease digestion. One plasmid DNA demonstrated the proper construction and was designated pKCEAInt2.

5

Final construction was effected by ligating the K-CEA fragment, including the trp promoter from pKCEAInt2 into pBR322(XAP). (pBR322(XAP) is prepared as described in U.S. Application 452,227, filed December 22, 1982; from pBR322 by deletion of the AvaI-PvuII fragment followed by ligation.)

10

The K-CEA fragment was prepared by treating pKCEAInt2 with Ava I, blunt ending with DNA polymerase I (Klenow fragment) in the presence of DNTPs, digestion with Pst I and isolation of the desired fragment by gel electrophoresis and electroelution.

15

The large vector fragment from pBR322(XAP) was prepared by successive treatment with EcoR I, blunt ending with polymerase, and redigestion with Pst I, followed by isolation of the large vector fragment by electrophoresis and electroelution.

20

The K-CEA and large vector fragments as prepared in the preceding paragraphs were ligated with T4 DNA ligase, and the ligation mixture transformed into E. coli as above. Plasmid DNA from several ampicillin resistant transformants were selected for analysis, and one plasmid DNA demonstrated the proper construction, and was designated pKCEAtrp207-I*.

25

E.1.8 Construction of a Plasmid Vector for Direct Expression of Mouse Mature Anti-CEA Heavy (Gamma 1) Chain Gene, p_γCEAtrp207-I*

30

Figure 7 illustrates the construction of p_γCEAtrp207-I*. This plasmid was constructed in two parts beginning with construction of the C-terminal region of the gamma 1 gene.

35

5 μ g of plasmid PHGH207-1* was digested with Ava I, extended to blunt ends with DNA polymerase I large fragment (Klenow fragment), extracted with phenol/ CHCl_3 , and ethanol precipitated. The DNA was digested with BamH I treated with BAP and the large fragment (fragment A) was purified by 6 percent polyacrylamide gel electrophoresis and electroelution.

10 -5 μ g of p γ 11 was digested with Pst I and the gamma chain cDNA insert fragment containing the C-terminal portion of the gene was purified, digested with Ava II followed by extension of the Ava II cohesive ends with Klenow, followed by Taq I digestion. The 375 basepair blunt ended Ava II to Taq I fragment (fragment B) was isolated and purified by gel electrophoresis and electroelution.

15 9 μ g of p γ 298 was digested with Taq I and BamH I for isolation of the 496 basepair fragment (fragment C).

20 Approximately equimolar amounts of fragments A, B, and C were ligated overnight at 14° in 20 μ l reaction mixture, then transformed into *E. coli* strain 294. The plasmid DNA from six ampicillin resistant transformants was committed to restriction endonuclease analysis and one plasmid DNA, named p γ CEAInt, demonstrated the correct construction of the C-terminal portion of gamma 1 (Figure 5).

25 To obtain the N-terminal sequences, 30 μ g of p γ 298 was digested with Pst I and the 628 basepair DNA fragment encoding the N-terminal region of mouse anti-CEA gamma chain was isolated and purified. This fragment was further digested with Alu I and Rsa I for isolation of the 280 basepair fragment. A 15 nucleotide DNA primer

30 met glu val met leu

5' ATG GAA GTG ATG CTG 3'

was synthesized by the phosphotriester method (supra).

35 The 5' methionine serves as the initiation codon. 500 ng of this synthetic oligomer primer was phosphorylated at the 5' end in a

reaction with 10 units T4 DNA kinase containing 0.5 mM ATP in 20 μ l reaction mixture. ~500 ng of the 280 basepair Alu I-Rsa I DNA fragment was mixed with the phosphorylated primer. The mixture was heat denatured for 3 minutes at 95° and quenched in dry-ice
5 ethanol. The denatured DNA solution was made 60mM NaCl, 7mM MgCl₂, 7 mM Tris HCl (pH 7.4), 12 mM in each dNTP and 12 units DNA Polymerase I--Large Fragment was added. After 2 hours incubation at 37°C, this primer repair reaction was phenol/CHCl₃ extracted, ethanol precipitated, and digested to completion with HpaII. ~50 ng
10 of the expected 125 basepair blunt-end to Hpa II DNA fragment (fragment D) was purified from the gel.

A second aliquot of py298 DNA was digested with Pst I, the 628 basepair DNA fragment purified by polyacrylamide gel
15 electrophoresis, and further digested with BamH I and Hpa II. The resulting 380 basepair fragment (fragment E) was purified by gel electrophoresis.

~5 μ g of pyCEAIntI was digested with EcoR I, the cohesive ends
20 were made flush with DNA polymerase I (Klenow), further digested with BamH I, treated with BAP and electrophoresed on a 6 percent polyacrylamide gel. The large vector fragment (fragment F) was isolated and purified.

In a three fragment ligation, 50 ng fragment D, 100 ng fragment E, and 100 ng fragment F were ligated overnight at 4° in a 20 μ l reaction mixture and used to transform E. coli K12 strain 294. The plasmid DNAs from 12 ampicillin resistant transformants were
25 analyzed for the correct construction and the nucleotide sequence surrounding the initiation codon was verified to be correct for the
30 plasmid named pyCEAInt2.

The expression plasmid, pyCEAtrp207-I* used for expression of the heavy chain gene is prepared by a 3-way ligation using the large
35

vector fragment from pBR322(XAP) (supra) and two fragments prepared from pYCEAInt2.

pBR322(XAP) was treated as above by digestion with EcoRI, blunt
5 ending with DNA polymerase (Klenow) in the presence of dNTPs,
followed by digestion with Pst I, and isolation of the large vector
fragment by gel electrophoresis. A 1543 base pair fragment from
pYCEAInt2 containing trp promoter linked with the N-terminal coding
region of the heavy chain gene was isolated by treating pYCEAInt2
10 with Pst I followed by BamH I, and isolation of the desired fragment
using PAGE. The 869 base pair fragment containing the C-terminal
coding portion of the gene was prepared by partial digestion of
pYCEAInt2 with Ava I, blunt ending with Klenow, and subsequent
digestion with BamH I, followed by purification of the desired
15 fragment by gel electrophoresis.

The aforementioned three fragments were then ligated under
standard conditions using T4 DNA ligase, and a ligation mixture used
to transform E. coli strain 294. Plasmid DNAs from several
20 tetracycline resistant transformants were analyzed; one plasmid DNA
demonstrated the proper construction and was designated
pYCEAtrp207-1*.

E.1.9 Production of Immunoglobulin Chains by E. coli
25 E. coli strain W3110 (ATTC No. 27325) was transformed with
pYCEAtrp207-1* or pKCEAtrp207-1* using standard techniques.

To obtain double transformants, E. coli strain W3110 cells were
transformed with a modified pKCEAtrp207-1*, pKCEAtrp207-1*Δ, which
30 had been modified by cleaving a Pst I-Pvu I fragment from the amp^R
gene and religating. Cells transformed with pKCEAtrp207-1*Δ are
thus sensitive to ampicillin but still resistant to tetracycline.
Successful transformants were retransformed using pYCEAInt2 which

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confers resistance to ampicillin but not tetracycline. Cells containing both pKCEAtrp207-1* and pYCEAInt2 thus identified by growth in a medium containing both ampicillin and tetracycline.

5 To confirm the production of heavy and/or light chains in the transformed cells, the cell samples were inoculated into M9 tryptophan free medium containing 10µg/ml tetracycline, and induced with indoleacrylic acid (IAA) when the OD 550 reads 0.5. The
10 induced cells were grown at 37°C during various time periods and then spun down, and suspended in TE buffer containing 2 percent SDS and 0.1 M β-mercaptoethanol and boiled for 5 minutes. A 10 x volume of acetone was added and the cells kept at 22°C for 10 minutes, then centrifuged at 12,000 rpm. The precipitate was suspended in
15 O'Farrell SDS sample buffer (O'Farrell, P.H., J. Biol. Chem., 250: 4007 (1975)); boiled 3 minutes, recentrifuged, and fractionated using SDS PAGE (10 percent), and stained with silver stain (Goldman, D. et al., Science 211: 1437 (1981)); or subjected to Western blot using rabbit anti-mouse IgG (Burnett, W. N., et al., Anal. Biochem. 112: 195 (1981)), for identification light chain and heavy chain.
20

Cells transformed with pYCEAtrp207-1* showed bands upon SDS PAGE corresponding to heavy chain molecular weight as developed by silver stain. Cells transformed with pKCEAtrp207-1* showed the proper
25 molecular weight band for light chain as identified by Western blot; double transformed cells showed bands for both heavy and light chain molecular weight proteins when developed using rabbit anti-mouse IgG by Western blot. These results are shown in Figures 8A, 8B, and 8C.

Figure 8A shows results developed by silver stain from cells
30 transformed with pYCEAtrp207-1*. Lane 1 is monoclonal anti-CEA heavy chain (standard) from CEA.66-E3. Lanes 2b-5b are timed samples 2 hrs, 4 hrs, 6 hrs, and 24 hrs after IAA addition. Lanes
35

2a-5a are corresponding untransformed controls; lanes 2c-5c are corresponding uninduced transformants.

Figure 8B shows results developed by Western blot from cells transformed with pKCEAtrp207-1*. Lanes 1b-6b are extracts from induced cells immediately, 1hr, 3.5 hrs, 5 hrs, 8 hrs, and 24 hrs after IAA addition, and 1a-6a corresponding uninduced controls. Lane 7 is an extract from a pyCEAtrp207-1* control, lanes 8, 9, and 10 are varying amounts of anti CEA-kappa chain from CEA.66-E3 cells.

Figure 8C shows results developed by Western blot from four colonies of double transformed cells 24 hours after IAA addition (lanes 4-7). Lanes 1-3 are varying amounts of monoclonal gamma chain controls, lanes 8 and 9 are untransformed and pyCEAtrp207-1* transformed cell extracts, respectively.

In another quantitative assay, frozen, transformed *E. coli* cells grown according to E.1.10 (below) were lysed by heating in sodium dodecyl sulfate (SDS)/ β -mercaptoethanol cell lysis buffer at 100°. Aliquots were loaded on an SDS polyacrylamide gel next to lanes loaded with various amounts of hybridoma anti-CEA. The gel was developed by the Western blot, Burnett (supra), using ¹²⁵I-labeled sheep anti-mouse IgG antibody from New England Nuclear. The results are shown in Figure 9. The figure shows that the *E. coli* products co-migrate with the authentic hybridoma chains, indicating no detectable proteolytic degradation in *E. coli*. Heavy chain from mammalian cells is expected to be slightly heavier than *E. coli* material due to glycosylation in the former. Using the hybridoma lanes as a standard, the following estimates of heavy and light chain production were made:

	(Per gram of cells)
<u>E. coli</u> (W3110/pyCEAtrp207-1*)	5 mg γ
<u>E. coli</u> (W3110/pKCEAtrp207-1*)	1.5 mg K
<u>E. coli</u> (W3110/pKCEAtrp207-1* Δ , pyCEAInt2)	0.5 mg K, 1.0 mg γ

E.1.10 Reconstitution of Antibody from Recombinant K and Gamma Chains

In order to obtain heavy and light chain preparations for reconstitution, transformed cells were grown in larger batches, harvested and frozen. Conditions of growth of the variously transformed cells were as follows:

E. coli (W3110/pyCEAtrp207-1*) were inoculated into 500 ml LB medium containing 5 µg/ml tetracycline and grown on a rotary shaker for 8 hours. The culture was then transferred to 10 liters of fermentation medium containing yeast nutrients, salts, glucose, and 2 µg/ml tetracycline. Additional glucose was added during growth and at OD 550 = 20, indoleacrylic (IAA), a trp derepressor, was added to a concentration of 50 µg/ml. The cells were fed additional glucose to a final OD 550 = 40, achieved approximately 6 hours from the IAA addition.

E. coli (W3110) cells transformed with pKCEA trp 207-1* and double transformed (with pKCEAtrp207-1* and pyCEAInt2) were grown in a manner analogous to that described above except that the OD 550 six hours after IAA addition at harvest was 25-30.

The cells were then harvested by centrifugation, and frozen.

E.2 Assay Method for Reconstituted Antibody

Anti-CEA activity was determined by ELISA as a criterion for successful reconstitution. Wells of microtiter plates (Dynatech Immulon) were saturated with CEA by incubating 100 µl of 2-5 µg CEA/ml solution in 0.1M carbonate buffer, pH 9.3 for 12 hours at room temperature. The wells were then washed 4 times with phosphate buffered saline (PBS), and then saturated with BSA by incubating 200 µl of 0.5 percent BSA in PBS for 2 hours at 37°C, followed by

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washing 4 times with PBS. Fifty microliters of each sample was applied to each well. A standard curve (shown in Figure 10), was run, which consisted of 50 μ l samples of 10 μ g, 5 μ g, 1 μ g, 500 ng, 100 ng, 50 ng, 10 ng, 5 ng and 1 ng anti-CEA/ml in 0.5 percent BSA in PBS, plus 50 μ l of 0.5 percent BSA in PBS alone as a blank. All of the samples were incubated in the plate for 90 minutes at 37°C.

The plates were then washed 4 times with PBS, and sheep anti-mouse IgG-alkaline phosphatase (TAGO, Inc.) was applied to each well by adding 100 μ l of an enzyme concentration of 24 units/ml in 0.5 percent BSA in PBS. The solution was incubated at 37°C for 90 minutes. The plates were washed 4 times with PBS before adding the substrate, 100 μ l of a 0.4 mg/ml solution of p-nitrophenylphosphate (Sigma) in ethanolamine buffered saline, pH 9.5. The substrate was incubated 90 minutes at 37°C for color development.

The A_{450} of each well was read by the Microelisa Auto Reader (Dynatech) set to a threshold of 1.5, calibration of 1.0 and the 0.5 percent BSA in PBS (Blank) well set to 0.000. The A_{450} data was tabulated in RS-1 on the VAX system, and the standard curve data fitted to a four-parameter logistic model. The unknown samples' concentrations were calculated based on the A_{450} data.

E.3 Reconstitution of Recombinant Antibody and Assay

Frozen cells prepared as described in paragraph E.1.10 were thawed in cold lysis buffer [10mM Tris HCl, pH 7.5, 1mM EDTA, 0.1M NaCl, 1mM phenylmethylsulfonyl fluoride (PMSF)] and lysed by sonication. The lysate was partially clarified by centrifugation for 20 mins at 3,000 rpm. The supernatant was protected from proteolytic enzymes by an additional 1mM PMSF, and used immediately or stored frozen at -80°C; frozen lysates were never thawed more than once.

The S-sulfonate of E. coli produced anti-CEA heavy chain (γ) was prepared as follows: Recombinant E. coli cells transformed with

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pyCEAtrp207-1* which contained heavy chain as insoluble bodies, were lysed and centrifuged as above; the pellet was resuspended in the same buffer, sonicated and re-centrifuged. This pellet was washed once with buffer, then suspended in 6M guanidine HCl, 0.1M Tris HCl, pH 8, 1mM EDTA, 20 mg/ml sodium sulfite and 10 mg/ml sodium tetrathionate and allowed to react at 25° for about 16 hrs. The reaction mixture was dialyzed against 8M urea, 0.1M Tris HCl, pH 8, and stored at 4°, to give a 3 mg/ml solution of γ -SSO₃.

650 μ l of cell lysate from cells of various *E. coli* strains producing various IgG chains, was added to 500 mg urea. To this was added β -mercaptoethanol to 20mM, Tris-HCl, pH 8.5 to 50mM and EDTA to 1mM, and in some experiments, γ -SSO₃ was added to 0.1 mg/ml. After standing at 25° for 30-90 mins., the reaction mixtures were dialyzed at 4° against a buffer composed of 0.1M sodium glycinate, pH 10.8, 0.5M urea, 10mM glycine ethyl ester, 5mM reduced glutathione, 0.1mM oxidized glutathione. This buffer was prepared from N₂-saturated water and the dialysis was performed in a capped Wheaton bottle. After 16-48 hours, dialysis bags were transferred to 4° phosphate buffered saline containing 1mM PMSF and dialysis continued another 16-24 hrs. Dialysates were assayed by ELISA as described in paragraph E.2 for ability to bind CEA. The results below show the values obtained by comparison with the standard curve in x ng/ml anti-CEA. Also shown are the reconstitution efficiencies calculated from the ELISA responses, minus the background (108 ng/ml) of cells producing K chain only, and from estimates of the levels of γ and K chains in the reaction mixtures.

	ng/ml anti-CEA	Percent recombination
<i>E. coli</i> W3110 producing IFN- α A (control)	0	--
<i>E. coli</i> (W3110/pKCEAtrp207-1*)	108	--
<i>E. coli</i> (W3110/pKCEAtrp207-1*), plus γ -SSO ₃	848	0.33
<i>E. coli</i> (W3110/pKCEAtrp207-1 Δ , pyCEAInt2)	1580	0.76
Hybridoma anti-CEA K-SSO ₃ and γ -SSO ₃	540	0.40

E.4 Preparation of Chimeric Antibody

Figures 11 and 12 show the construction of an expression vector for a chimeric heavy (gamma) chain which comprises the murine anti CEA variable region and human γ -2 constant region.

A DNA sequence encoding the human gamma-2 heavy chain is prepared as follows: the cDNA library obtained by standard techniques from a human multiple myeloma cell line is probed with 5' GGGCACTCGACACAA 3' to obtain the plasmid containing the cDNA insert for human gamma-2 chain (Takahashi, et al., Cell, 29: 671 (1982), incorporated herein by reference), and analyzed to verify its identity with the known sequence in human gamma-2 (Ellison, J., et al., Proc. Natl. Acad. Sci. (USA), 79: 1984 (1982) incorporated herein by reference).

As shown in Figure 11, two fragments are obtained from this cloned human gamma 2 plasmid (py2). The first fragment is formed by digestion with PvuII followed by digestion with Ava III, and purification of the smaller DNA fragment, which contains a portion of the constant region, using 6 percent PAGE. The second fragment is obtained by digesting the py2 with any restriction enzyme which cleaves in the 3' untranslated region of γ 2, as deduced from the nucleotide sequence, filling in with Klenow and dNTPs, cleaving with Ava III, and isolating the smaller fragment using 6 percent PAGE. (The choice of a two step, two fragment composition to supply the PvuII-3' untranslated fragment provides a cleaner path to product due to the proximity of the AvaIII site to the 3 terminal end thus avoiding additional restriction sites in the gene sequence matching the 3' untranslated region site.) pyCEA207-1* is digested with EcoR I, treated with Klenow and dNTPs to fill in the cohesive end, and digested with Pvu II, the large vector fragment containing promoter isolated by 6 percent PAGE.

The location and DNA sequence surrounding the PvuII site in the

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mouse gamma-1 gene are identical to the location and DNA sequence surrounding the PvuII site in the human gamma-2 gene.

5 The plasmid resulting from a three way ligation of the foregoing fragments, pChim1, contains, under the influence of trp promoter, the variable and part of the constant region of murine anti-CEA gamma 1 chain, and a portion of the gamma 2 human chain. pChim1 will, in fact, express a chimeric heavy chain when transformed into E. coli, but one wherein the change from mouse to human does not
10 take place at the variable to constant junction.

15 Figure 12 shows modification of pChim1 to construct pChim2 so that the resulting protein from expression will contain variable region from murine anti CEA antibody and constant region from the human γ -2 chain. First, a fragment is prepared from pChim1 by treating with Nco I, blunt ending with Klenow and dNTPs, cleaving with Pvu II, and isolating the large vector fragment which is almost the complete plasmid except for short segment in the constant coding
20 region for mouse anti CEA. A second fragment is prepared from the previously described py2 by treating with Pvu II, followed by treating with any restriction enzyme which cleaves in the variable region, blunt ending with Klenow and dNTPs and isolating the short fragment which comprises the junction between variable and constant
25 regions of this chain.

30 Ligation of the foregoing two fragments produces an intermediate plasmid which is correct except for an extraneous DNA fragment which contains a small portion of the constant region of the murine anti CEA antigen, and a small portion of the variable region of the human gamma chain. This repair can be made by excising the Xba I to Pvu II fragment and cloning into M13 phage as described by Messing et al., Nucleic Acids Res. 9: 309 (1981), followed by in vitro site directed deletion mutagenesis as described by Adelman, et al., DNA 2, 183 (1983) which is incorporated herein by reference. The
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Xba I-Pvu II fragment thus modified is ligated back into the intermediate plasmid to form pChim2. This plasmid then is capable of expressing in a suitable host a cleanly constructed murine variable/human constant chimeric heavy chain.

5

In an analogous fashion, but using mRNA templates for cDNA construction for human kappa rather than γ chain, the expression plasmid for chimeric light chain is prepared.

- 10 The foregoing two plasmids are then double transformed into E. coli W3110, the cells grown and the chains reconstituted as set forth in paragraph E.1-E.3 supra.

E.5 Preparation of Altered Murine Anti-CEA Antibody

15

E.5.1 Construction of Plasmid Vectors for Direct Expression of Altered Murine Anti-CEA Heavy Chain Gene

- The cysteine residues, and the resultant disulfide bonds in the region of amino acids 216-230 in the constant region of murine anti-CEA heavy chain are suspected to be important for complement fixation (Klein, et al., Proc. Natl. Acad. Sci., (USA), 78: 524 (1981)) but not for the antigen binding property of the resulting antibody. To decrease the probability of incorrect disulfide bond formation during reconstitution according to the process of the invention herein, the nucleotides encoding the amino acid residues 226-232 which includes codons for three cysteines, are deleted as follows:

- 30 A "deleter" deoxyoligonucleotide, 5' CTACACCATGTCAGGGT is used to delete the relevant portions of the gene from p γ CEAtrp207-1* by the procedure of Wallace, et al., Science, 209: 1396 (1980) or of Adelman, et al., DNA 2, 183 (1983). Briefly, the "deleter" deoxyoligonucleotide is annealed with denatured p γ CEAtrp207-1* DNA,

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and primer repair synthesis carried out in vitro, followed by screening by hybridization of presumptive deletion clones with p³² labelled deleter sequence.

5 E.5.2 Production of Cysteine Deficient Altered Antibody

The plasmid prepared in E.5.1 is transformed into an E. coli strain previously transformed with pKCEAtrp207-1* as described above. The cells are grown, extracted for recombinant antibody chains, and the altered antibody reconstituted as described in
10 E.1.10.

E.6 Preparation of Fab

15 E.6.1 Construction of a Plasmid Vector for Direct Expression of Murine Anti-CEA Gamma 1 Fab Fragment Gene
pyCEAFabtrp207-1*

Figure 13 presents the construction of pyCEAFabtrp207-1*. 5 µg of pBR322 was digested with Hind III, the cohesive ends made flush by treating with Klenow and dNTPs; digested with Pst I, and treated
20 with BAP. The large vector fragment, fragment I, was recovered using 6 percent PAGE followed by electroelution.

5 µg of pyCEAtrp207-1* was digested with both BamH I and Pst I and the -1570 bp DNA fragment (fragment II) containing the trp promoter and the gene sequence encoding the variable region
25 continuing into constant region and further into the anti-CEA gamma 1 chain hinge region, was isolated and purified after electrophoresis.

30 Expression of the anti-CEA gamma 1 chain Fab fragment rather than complete heavy chain requires that a termination codon be constructed at the appropriate location in the gene. For this, the 260 bp Nco I - Nde I DNA fragment from 20 µg of the py298 was isolated and purified. A 13 nucleotide DNA primer, the complement
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of which encodes the last 3 C-terminal amino acids of the Fab gene and 2 bases of the 3 needed for the stop codon, was synthesized by the phosphotriester method (supra). The probe hybridizes to nucleotides 754 to 767 (Figure 4) which has the following sequence:

AspCysGlyStop

5' GGGATTGTGGTTG 3'

The third base of the stop codon is provided by the terminal nucleotide of the filled-in Hind III site from pBR322 cleavage described above. 500 ng of this primer was used in a primer repair reaction by phosphorylation at the 5' end in a reaction with 10 units T4 DNA kinase containing 0.5 mM ATP in 20 μ l, and mixing with ~200 ng of the Nco I-Nde I DNA fragment. The mixture was heat denatured for 3 minutes at 95° and quenched in dry-ice ethanol. The denatured DNA solution was made 60mM NaCl, 7mM MgCl₂, 7 mM Tris HCl (pH 7.4), 12 mM in each dNTP and 12 units DNA Polymerase I-Large Fragment was added. After 2 hours incubation at 37°C, this primer repair reaction was phenol/CHCl₃ extracted, ethanol precipitated, digested with BamH I and the reaction electrophoresed through a 6 percent polyacrylamide gel. ~50 ng of the 181 bp blunt end to BamH I DNA fragment, fragment III, was isolated and purified.

~100 ng of fragment I, ~100 ng each of fragments II and III were ligated overnight and transformed into E. coli K12 strain 294. Plasmid DNA from several tetracycline resistant transformants was analyzed for the proper construction and the nucleotide sequence through the repair blunt end filled-in Hind III junction was determined for verification of the TGA stop codon.

E.6.2 Production of Fab Protein

The plasmid prepared in E.6.1 is transformed into an E. coli strain previously transformed with pKCEAtrp207-1* as described above. The cells are grown, extracted for recombinant antibody chains and the Fab protein reconstituted as described in E.1.10.

The appended claims set out the principal areas for which a monopoly is presently claimed. In addition, the following preferred features should be noted:

- 5 the antibody of claim 3 which is directed against CEA;
- the antibody of claim 3 wherein the heavy chain is of the gamma family;
- the antibody of claim 3 wherein the light chain is of the kappa family;
- the composition of matter of claim 8 which is
- 10 mammalian;
- the composition of matter of claim 8 which is immunoreactive against CEA;
- the sequence of claim 9 which is a mammalian heavy chain;
- 15 the sequence of claim 9 which is anti-CEA heavy chain;
- the sequence of claim 10 which is a mammalian light chain;
- the sequence of claim 10 which is anti-CEA light chain;
- 20 the recombinant host cells of claim 16 which are microbial host cells;
- the method of claim 17 wherein the vector of b) and the vector of d) are transformed into the same host cell culture, and
- 25 the sequence of a) and the sequence of c) are inserted into the same replicable expression vector;
- the method of claim 17 wherein the DNA sequence of a) encodes mammalian heavy chain, and the DNA sequence of c) encodes mammalian light chain; and wherein both DNA
- 30 fragments encode amino acid sequences of the same mammalian antibody;
- the method of claim 17 wherein the DNA fragment of a) encodes a chimeric hybrid heavy chain and the DNA sequence of c) encodes a chimeric light chain; and
- 35 the method of any one of claims 17 to 19 wherein said vectors are transformed into the same host cell culture.

CLAIMS

1. An immunoglobulin produced by recombinant host cells.
- 5 2. An immunoglobulin substantially free of other proteins with which it is normally associated in vertebrate cells.
3. The immunoglobulin of claim 1 or 2 which is a mammalian antibody, in that the amino acid sequences of all
10 four chains are homologous to the sequences in the corresponding chains in an antibody derived from a mammalian species.
4. The immunoglobulin of claim 1 or 2 which is a hybrid
15 antibody, a composite non-specific immunoglobulin, a chimeric antibody, or an altered antibody.
5. A chimeric antibody of claim 4 wherein the constant regions of all four chains are homologous to the
20 corresponding constant regions of an antibody of a first mammalian species, and the amino acid sequence of the variable regions of all four chains are homologous to the variable regions in an antibody derived from a second, different, mammalian species.
- 25 6. A composition of matter consisting essentially of a univalent antibody.
7. A composition of matter consisting essentially of Fab
30 protein.
8. A composition of matter of claim 6 or claim 7 which is produced by recombinant host cells.
- 35 9. A sequence of amino acids produced by recombinant host cells corresponding to immunoglobulin heavy chain.

10. A sequence of amino acids produced by recombinant host cells corresponding to immunoglobulin light chain.
11. A sequence of claim 9 or claim 10 which is a chimeric heavy chain or light chain, respectively.
12. A sequence of claim 11 wherein that portion of the sequence which corresponds to the constant region is homologous to corresponding sequence of an antibody derived from humans, and the amino acid sequence of the variable region is homologous to the corresponding amino acid sequence of an antibody derived from non-human mammalian species.
13. A DNA sequence which encodes for the immunoglobulin of claim 1 or 2, the composition of matter of claim 6 or the amino acid sequence of claim 9 or claim 10.
14. A replicable expression vector capable of expressing in a suitable host cell the DNA sequence of claim 13.
15. An expression plasmid which comprises the DNA sequence of claim 14 operably linked to a promoter compatible with a suitable host cell.
16. Recombinant host cells or host cell cultures transformed with the vector of claim 14 or 15.
17. A method for preparing immunoglobulins in recombinant host cells which method comprises
- a) preparing a DNA sequence encoding heavy chain,
 - b) inserting the sequence of a) into a replicable expression vector operably linked to a suitable promoter,
 - c) preparing a DNA sequence encoding light chain,
 - d) inserting the sequence of c) into a replicable expression vector operably linked to a suitable promoter,

e) transforming host cell culture with the vector of
b) and host cell culture with the vector of d),

f) recovering light chain and heavy chain from cell
culture,

- 5 g) reconstituting light and heavy chain,
wherein steps f) and g) may be performed either
sequentially in either order, or simultaneously.

18. A method for preparing Fab protein in recombinant
10 host cells which method comprises

a) preparing a DNA sequence encoding the Fab region
of heavy chain,

b) inserting the sequence of a) into a replicable
expression vector operably linked to a suitable promoter,

- 15 c) preparing a DNA sequence encoding light chain,

d) inserting the sequence of c) into a replicable
expression vector operably linked to a suitable promoter,

e) transforming host cell culture with the vector of
b) and host cell culture with the vector of d),

- 20 f) recovering light chain and Fab protein of heavy
chain from cell culture,

g) reconstituting light and heavy Fab region chains;
wherein steps f) and g) may either be performed
sequentially in either order or simultaneously.

- 25 19. A method for preparing univalent antibody in
recombinant host cells which method comprises

a) preparing a DNA sequence encoding heavy chain,

- 30 b) inserting the sequence of a) into a replicable
expression vector operably linked to a suitable promoter,

c) preparing a DNA sequence encoding light chain,

d) inserting the sequence of c) into a replicable
expression vector operably linked to a suitable promoter,

- 35 e) preparing a DNA sequence encoding the Fc portion
of heavy chain,

- f) inserting the sequence of e) into a replicable expression vector operably linked to a suitable promoter,
- g) transforming host cell culture with the vector of b), host cell culture with the vector of d), and host cell culture with the vector of f),
- h) recovering light chain, heavy chain, and Fc portion of heavy chain from cell culture,
- i) reconstituting light chain, heavy chain, and Fc portion of heavy chain,
- wherein steps h) and i) may be performed sequentially in either order or simultaneously.
20. A method for preparing heavy chain or light chain which method comprises
- a) preparing a DNA sequence encoding heavy or light chain,
- b) inserting said sequence into a replicable expression vector operably linked to a suitable promoter,
- c) transforming host cell culture with the vector of b), and
- d) recovering heavy or light chain from cell culture.
21. A method for preparing Fab region of heavy chain as a polypeptide which method comprises
- a) preparing a DNA sequence encoding Fab region of heavy chain,
- b) inserting said sequence into a replicable expression vector operably linked to a suitable promoter,
- c) transforming host cell culture with the vector of b),
- d) recovering Fab region of heavy chain from cell culture.

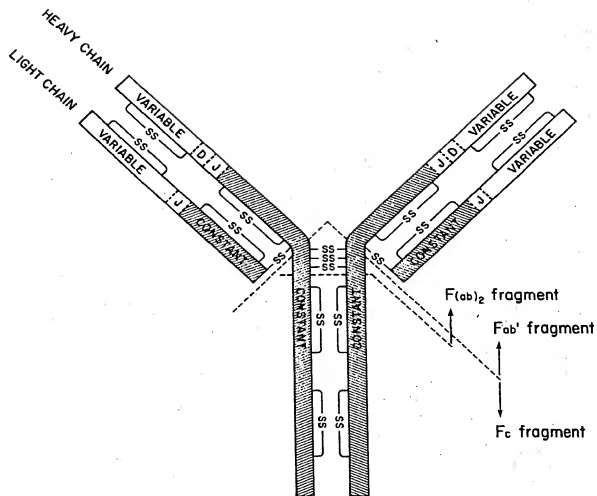


Fig.1.

2/A

1 GTTGCTGTGG TTGCTGTGG TTGAAGGAGA CATTGTGATG ACCCAGCTCT ACAATTTCAT GTCCACATCA GTAGGAGACA GGGTCAGCAT CACCTGCAG
CAACGACACC AACAGACC AACCTCTCT GTAACTACATCG TGGGTGAGAG TGTTTAAGTA CAGGTGTAGT CATCTCTGT CATCTGTGA GTGACCTTC
tth111 hae1
hinc11

101 GCCAGTCAGG ATGTGGGTGC TGCATATAGCC TGGTATCAAC AGAACCCAGG ACATCTCT AACTACTGA TTACTGGGC ATCCACCGG CACACTGGG
CGGTGCTGC TACACCACG AGCATATGG ACCATAGTGG TCCTTGGTGC TGTAAAGA TTGATGACT foki sfa1
scr11
ncl11 hinf1

201 TCCCTGATCG CTTCACAGC AGTGGATCTG GGACAGATT CACTCTACC ATTAGCAATG TGCAGTCTGA TGACTTGGCA GATTATTCT GTCAACAATA
AGGACTAGC GAAGTGTCC TCACCTAGAC CCTGTCTAAG GTGAGAGTGG TAATCGTTAC ACCTCAGCT ACTGAACCGT ACTAAGA CAGTTGTAT
xho11
sau3A
dnl1 hinc11

301 TAGCGGGTAT CCTCTCAGT TCGGTCTGG GACCAAGCTG GAGCTGAAC GGGCTGATGC TGCACCAAT GTATCATCT TCCACCATC CAGTGCAGC
ATCGCCCAT GAGAGTGA AGCCACGACC CTGGTTGAC CTGCACTTG CCGACTAGG AGGTGTTGA CATAGGTGA AGGTGTTGA GTCACTGCT
mnl1 sau96 fnu4H1
ava11 alu1 sfa1
bbv mbo11
hpa1

401 TTAACATCTG GAGTGCCTC AGTCTGTGTG TTCTTGACCA ACTCTACCC CAAGACATC AATGTCAAT GTCAAGTGA TGGCAGTGA CGACAAATG
AATTGTAGAC TCCACAGAG TCAGACACG AGCACTTGT TGAAGTGG GTTCTGTAG TTACAGTCA CTTCTCACT ACCGCTACT CGTGTTTAC
mnl1 mnl1 xmn1
dcl1

acy1

Fig.2A.

Fig. 2B.

nucleotides: 882


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1      hinfI      sau96      ddel      aluI      sfaI
      GAGTCAGCAC TGAACAGGGA CCGCTCAGCA TGAACCTGG GCTCAGCTTG ATTACCTTG TCCITGTTT AAAAGTTGC CAGTGTGAAG TGATCTGGT
      CTCAGTGGTG ACTTGTCCT GGGGAGTGCT ACTTGAGCC CGAGTCEAG TAAATGGAC AGGAACAAA TTTTCAACG GTCACACTTC ACTAGACCA

scrFI sau96
101      hinfI      hinfI      ecorII      auaI      hnfI      hnfI
      GGAGCTGGGG GAGCTCTTAA TGGAGCTGG AGGCTCCCTG AAACCTCTCT GTGACAGCTC TGGATTCACT TTGAGTAGAT ATGCCATGTC TTGGGTTCGC
      CCTCAGACCC CTTAGAAAT ACCTCGGACC TCCAGGGAC TTGAGAGGA CAGTCCGGAG ACCTAAGTGA AAGTCACTA TAGGGTACAG ACCCAAGCG

hpaII mnlI
201      hinfI      hpaII      hnfI      hnfI      hnfI      hnfI
      CAGACTCCGG AGAGAGGCT GGAGTGGGTC GCATCATTA CTAGTGTGG TACTTCACAG CTTCATCCA GACAGTGTGA AGGGCATC ACCATCTCCA
      GTCTGAGGCG TCTTCTCGA CTTCAACCCAG GCTTGGTAA TATCACCACC ATCAGTGTG GAGGTAGGT CTGTACACT TCCCGCTAG TGGTAGGCT

fokI
301      hpaII      rsaI      mnlI      ddel      haeIII      mnlI
      GAGACATGCG CAAGACACC CTGTACTTGC AATGAGCAG TCTGAGGTCT GAGGACAGCG CCACTGATTA CTGTSCAGA CCCCCTCTTA TTTCGTTAGT
      CTCGTGTACG GTTCTGTGG GACATGGAGG TTTACTGTC AGACTCCAG CTCCTGTGCC GGTACATAA GACACGTTCT GGGGGAGAAAT AAGCAATCA

xhoII      scrFI      sau96      sau3A      ecorII
401      hpaII      mnlI      ddel      hpaII      ddel      hpaII      dpaI
      AGCGGACTAT GCTATGGACT ACTGGBGTTA AGGACCTCA GTACCCGTCT CCTCAGCCA AAGGACACC CCATCTGTCT ATCCACTGGC CCTTGGATCT
      TGCCTGATA CGATACCTGA TGACCCAGT TCCTTGGAGT CAGTGGCAGA GGAGTGGTT TTGCTGTGGG GGTAGACAGA TAGGTGACCG GGGACCTAGA

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Fig. 4A.

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Fig. 4C.

Fig. 4C.

250 ile phe pro pro lys pro lys asp val leu thr thr ile thr leu thr pro lys val thr cys val val asp ile ser lys asp asp pro
 AUC UUC CCC CCA AAG CCC AAG GAG GUG CUC ACC AUU ACU CUG ACU CCG AAG GUC GUA GUG GUA GAC AUC AGC AAG GAG GAU CCC
 270
 glu val gln phe ser trp phe val asp asp val glu val his thr ala gln thr gln pro arg glu glu phe asn ser thr phe arg
 GAG GUC CAG UUC AGC UGG UUU GUA GAU GAU GUG GAG GUG CAC ACA GCU CAG ACG CAA CCC CGG GAG GAG CAG UUC AAC AGC ACU UUC CCG
 290
 ser val ser glu leu pro ile met his gln asp trp leu asn gly lys phe lys cys arg val asn ser ala ala phe pro ala pro
 UCA GUC AGU GAA CUU CCC AUC AUG CAG CAG GAC UGG CUC AAU GGC AAG GAG UUC AAA UGC AGG GUC AAC AGU GCA GCU UUC CCU GCG CCC
 310
 ile glu lys thr ile ser lys thr lys gly arg pro lys ala pro gln val tyr thr ile pro pro lys glu gln met ala lys asp
 AUC GAG AAA ACC AUC UCC AAA ACC AAA GGC AGA CCG AAG GCU CCA CAG GUG UAC ACC AUU CCA CCU CCC AAG GAG CAG AUG GCC AAG GAU
 330
 lys val ser leu thr cys met ile thr asp phe phe pro glu asp ile thr val glu trp gln trp asn gly gln pro ala glu asn tyr
 AAA GUC AGU CUG ACC UGC AUG AUA ACA GAC UUC UUC CCG GAA GAC AUU ACU GUG GAG UGG CAG UGG AAU GGG CAG CCA GCG GAG AAC UAC
 350
 lys asn thr gln pro ile met asn thr asn gly ser thr phe val tyr ser lys cys asn val gln lys ser asn trp glu ala gly asn
 AAG AAC ACU CAG CCC AUC AUG AAC ACG AAU GGC UCU UAC UUC GUC UAC AGC AAG CUC AAU GUG CAG AAG AGC AUC UGG GAG GCA GGA AAU
 370
 thr phe thr cys ser val leu his gln glu leu his asn his thr glu lys ser leu ser his ser pro gly lys op
 ACU UUC ACC UGC UCU GUG UUA CAU GAG GGC CUG CAG CAC AAC CAC CAU ACU GAG AAG AGC CUC UCC CAC UCU CCU GGU AAA UGA UCCAGAGUCCU
 390
 UGAGGCCUCUGGUCUACAGGACUCUGACACUACUCCACCCUCCUUGUAUAAUAAAGCACCCAGCACUGCCUUGGGAAAAA
 410
 430
 440
 447

Fig. 5B.

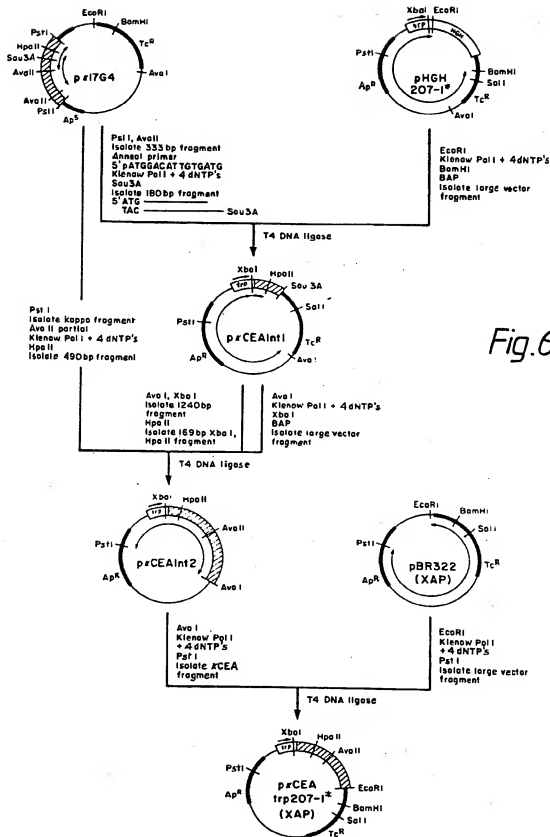


Fig.6.

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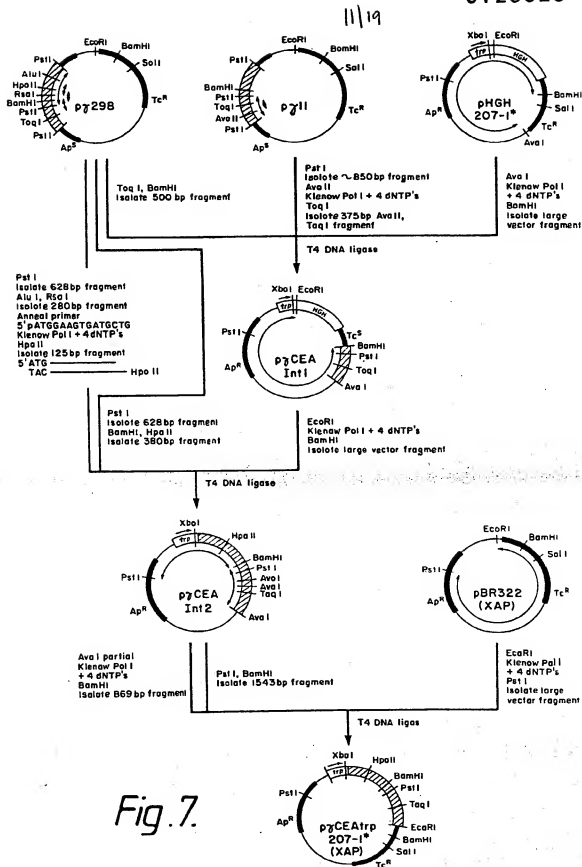


Fig. 7.

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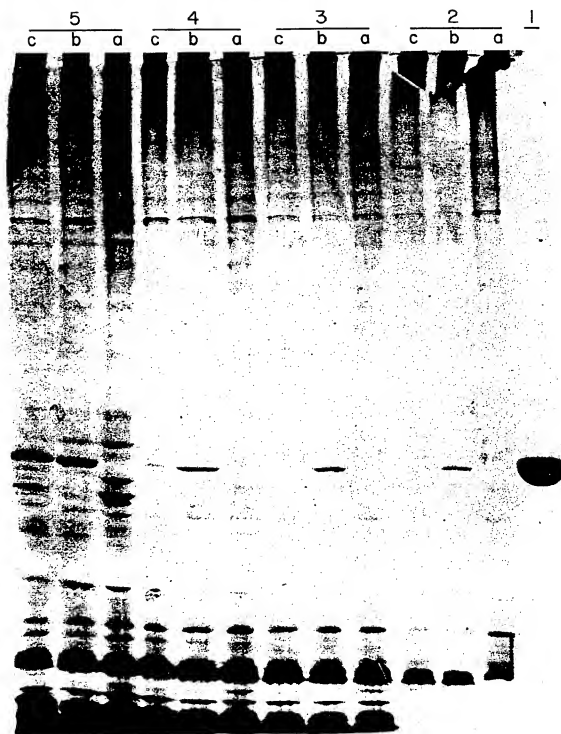
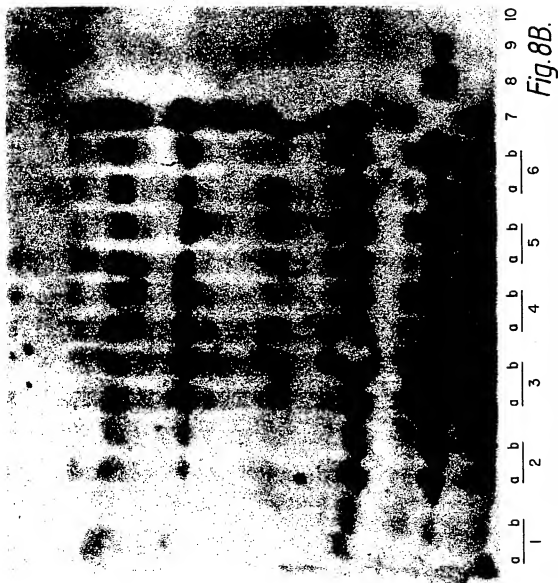


Fig. 8A.

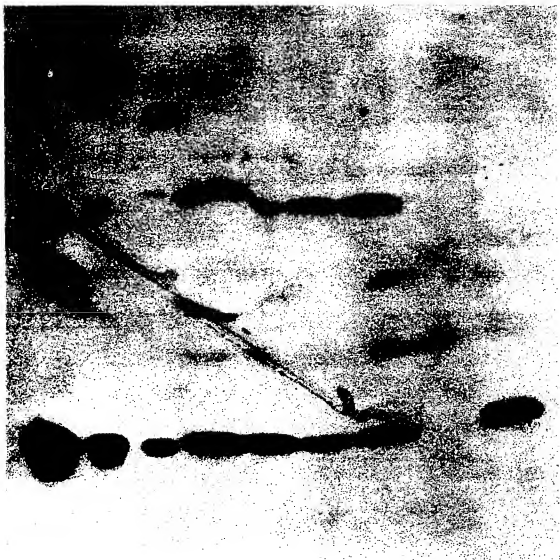
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1 2 3 4 5 6 7 8 9

Fig. 8C.

0.10 μ g anti-CEA
 0.30 μ g anti-CEA
 1.00 μ g anti-CEA
 K cells (10 μ l)
 γ cells (10 μ l)
 K γ cells (10 μ l)
 RW57 - K3000
 RW57 - K3000
 31-35 } K-G75
 31-35 }
 K γ cells (20 μ l)
 K cells (20 μ l)

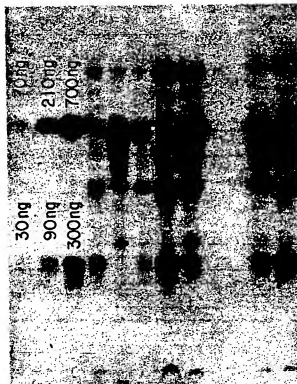


Fig.9.

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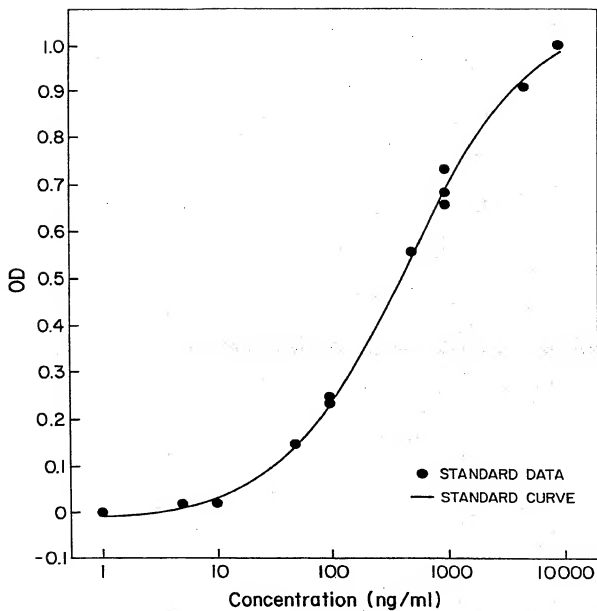


Fig. 10.

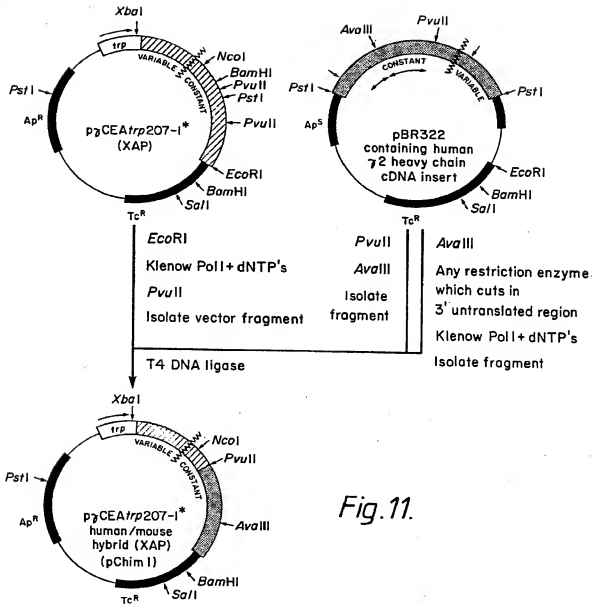
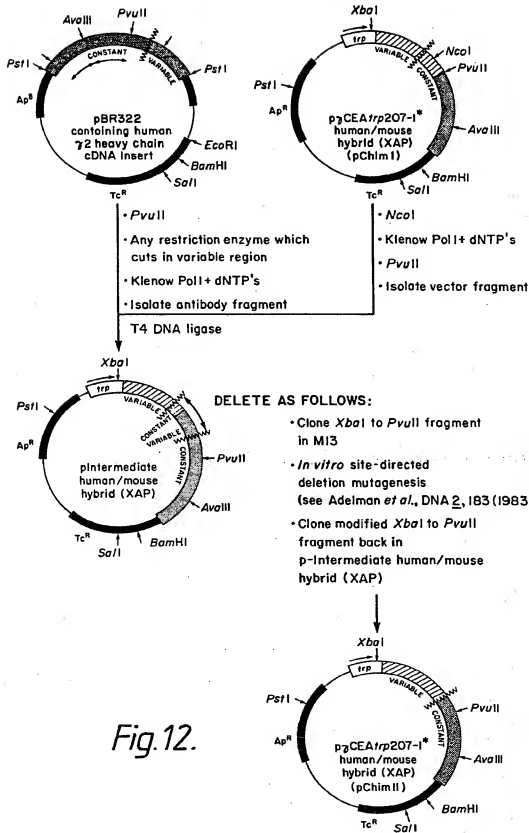


Fig. 11.



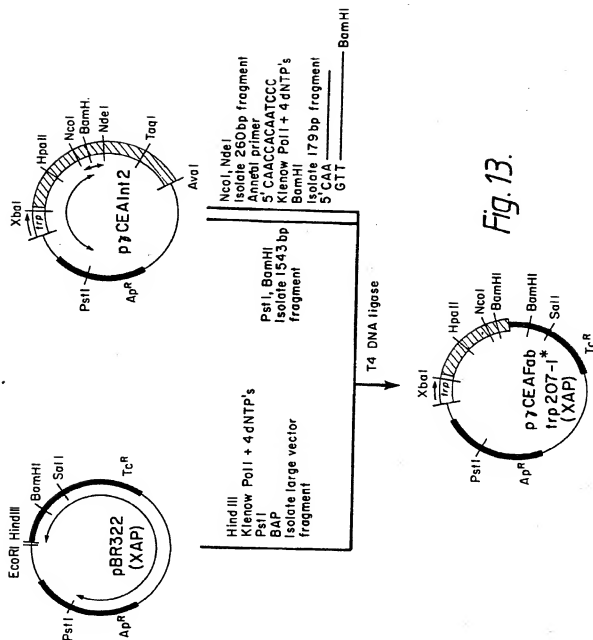


Fig.13.

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EUROPEAN SEARCH REPORT

0125023

Application number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 84302368.0
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
X	EP - A2,A3 - 0 068 763 (UNIVERSITY OF TEXAS) * Claims 1,10; page 4, line 15 - page 5, line 1 *	1,4,8-10	C 12 N 15/00 C 12 P 21/00 A 61 K 39/395
A,D	TRENDS IN BIOCHEMICAL SCIENCES, vol. 6, no. 8, August 1981, North-Holland N. GOUGH "The rearrangements of immunoglobulin genes" pages 203-205		
A,D	PROCEEDINGS OF THE NATIONAL ACADEMY of SCIENCES OF THE UNITED STATES OF AMERICA, vol. 77, no. 4, April 1980 G. KÖHLER "Immunoglobulin chain loss in hybridoma lines" page 2197-2199		TECHNICAL FIELDS SEARCHED (Int. Cl. 7) C 12 N C 12 P A 61 K
A,D	THE JOURNAL OF IMMUNOLOGY, vol. 123, no. 2, August 1979, Baltimore, U.S.A. S.L. MORRISON "Sequentially derived mutants of the constant region of the heavy chain of murine immunoglobulins" page 793-800		
A	EP - A2 - 0 057 107 (COATS PATONS)		
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 11-07-1984	Examiner FARNIOK
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